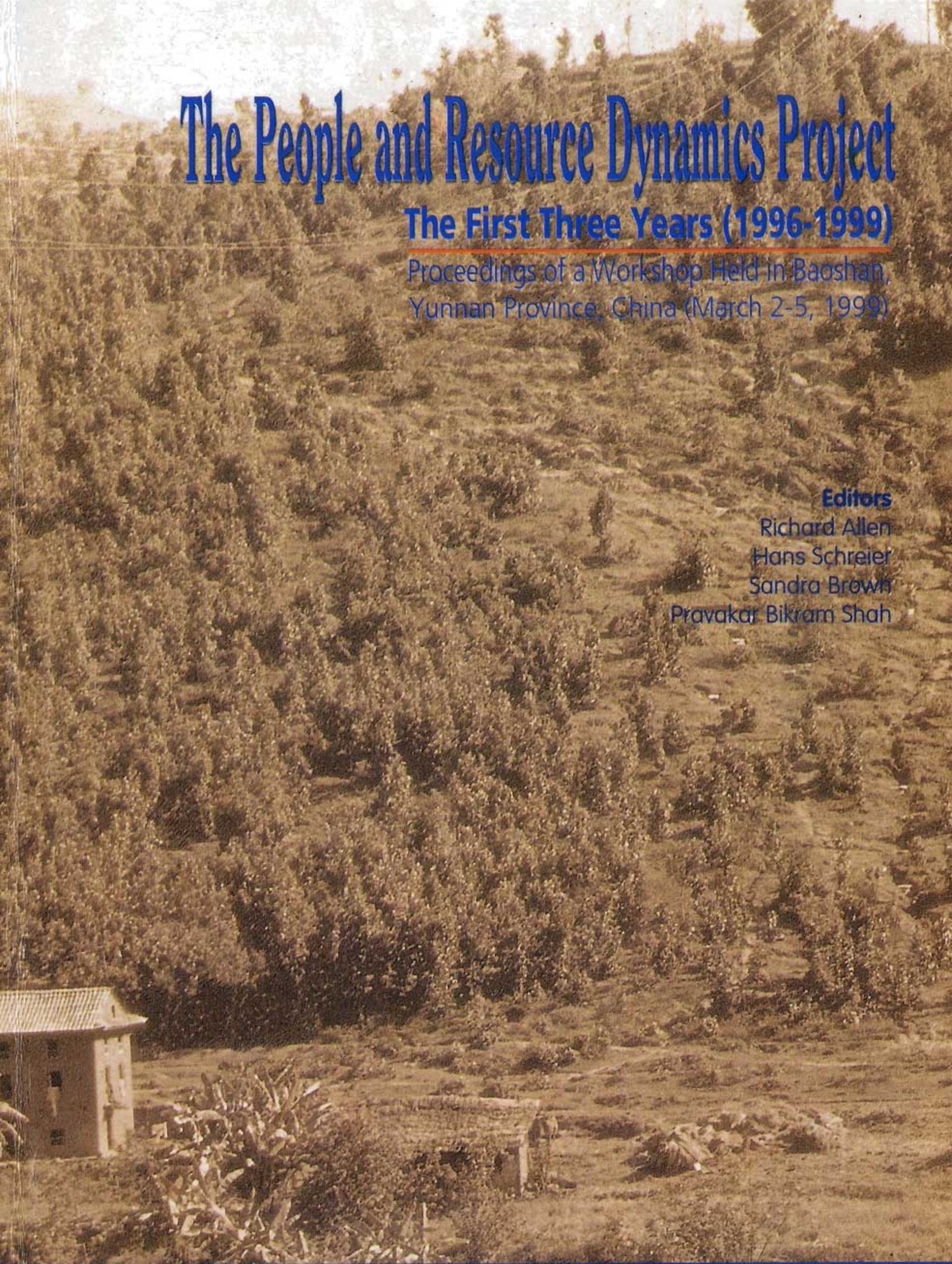

The People and Resource Dynamics Project

The First Three Years (1996-1999)

Proceedings of a Workshop Held in Baoshan, Yunnan Province, China (March 2-5, 1999)

Editors
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Hans Schreier
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IDRC
CANADA

ICIMOD

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Cover Plate
Kubinde rehabilitation site (front) - B. Shrestha
Collecting fuelwood (China) (back/inside front cover) - PARDYP File Photo
Transporting manure to the fields (India) (back/inside front cover) - PARDYP File Photo
Preparing for plantation (Nepal) (back/inside front cover) - PARDYP File Photo
Women farmers (Pakistan) (back/inside front cover) - PARDYP File Photo

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Editorial Team
A. Beatrice Murray Shrestha (Editor)
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Foreword

The behaviour of water on mountain slopes, and its interaction with soil as it drains rapidly downwards, provides much of the distinctive determinants of mountain farming systems. The long- term productivity of the diverse agricultural regimes employed by mountain farmers in the Hindu Kush-Himalayas depends on these dynamic and complex water-soil relationships. This nexus is further embedded in wider systems of social, institutional, and economic relations which are, in part, distinctive to mountains—and are themselves undergoing dynamic changes.

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' Project (PARDYP). Based on research undertaken by these two previous projects in the middle mountains of Nepal and, to some extent, in other countries of the region, PARDYP was conceptualised in 1996. This new follow-on project is based on regional collaboration throughout the Hindu Kush-Himalaya region. The Swiss Development Cooperation (SDC) joined the International Development Research Centre of Canada in providing funding and intellectual support.

The primary objectives of PARDYP are to provide research for development through understanding the processes of natural resource degradation and through recommending sustainable community and farm-based methods of promoting rehabilitation. The project focuses on improving degraded lands. 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 daily management of project sites is undertaken by collaborating focal institutions in China, India, Pakistan, and Nepal. The participating scientists from these countries are the projects' 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) and Bern (Switzerland). We are confident that the work carried out by PARDYP will contribute to better management of mountain natural resources and help reduce the spectre of poverty in agricultural communities throughout the Hindu Kush-Himalayas.

J. Gabriel Campbell
Director General, ICIMOD

Executive Summary

This document comprises papers presented at the Final Phase I Workshop of the People and Resource Dynamics Project (PARDYP), held in China in March 1999. This project is funded by the Swiss Agency for Development and Cooperation (SDC), the International Development Research Council (IDRC, Canada), and the International Centre for Integrated Mountain Development (ICIMOD). PARDYP Phase I began in October 1996 and ended in September 1999, and has been active at the watershed scale in four of ICIMOD's eight member countries—China, India, Nepal, and Pakistan.

PARDYP is a research for development project which evolved from two previous IDRC-funded projects concerned with investigations into 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 several important lessons. It was learned that geographical generalisations are not appropriate unless long-term results from replicated tests and trials are available, that water is as important as soils in terms of both dynamics and sustainability, that institutional and policy settings must be supportive in order to obtain sustainable development, and that common methodologies and scientific rigour are of key importance in monitoring biophysical parameters and changes. The PARDYP project was developed during a 1996 planning workshop on the basis of these lessons learnt, the need for longer-term data generation and field study, and the necessity to work more closely with the watershed communities.

The primary objectives of PARDYP Phase I were to provide a basic understanding of the natural resource degradation processes, to recommend proven strategies and programmes for community and farm-based prevention of degradation, and to promote rehabilitation and improved management of the natural resources using five watersheds of the HKH region as an example.

ICIMOD was the central executive agency but the project was undertaken through strong partnerships with many collaborators. Specialists from the Universities of British Columbia (Canada) and Bern (Switzerland) provided technical back-up. In China, India, and Pakistan, focal institutions undertook the day-to-day management of the project in the selected watersheds: the Kunming Institute of Botany in Kunming, China; the GB Pant Institute for

Himalayan Environment and Development in Almora, India; and the Pakistan Forest Institute in Peshawar, Pakistan. Each of these focal institutions identified their own key national partners from other government offices, local NGOs, and grass roots organisations. Project staff members at ICIMOD managed and undertook the activities in Nepal, also alongside a large number of different partners.

In some of the fields of study, for example the hydrological and erosion plot studies, standard methodologies were developed for all five watersheds. In others, greater flexibility was permitted in order that the methods used were appropriate to the customs and traditions of the particular watershed society. In all aspects, emphasis was placed on participatory research and management.

Some common goals were achieved in all the watersheds during PARDYP Phase I. The following were established.

- National core teams, including the identification of key resource partners, institutes, and line agencies
- A basic research network—a total of 27 hydrological stations, 43 meteorological stations, and 23 erosion plots in the five watersheds
- Common land rehabilitation and reclamation areas—14 in all

In addition, the following were carried out.

- Training of local watershed residents in maintaining and monitoring the stations and plots, and managing the common land activities and participatory on-farm research
- Socioeconomic, farming systems, and gender research surveys, as well as PRA training and surveys
- Land use, soil, and geology surveys with subsequent GIS mapping work
- Agricultural and horticultural trials
- Collection of social, economic, and biophysical basic data and establishment of databases
- Production of Annual Yearbooks collating the hydrological and meteorological results
- Analysis of some of the early results of the research

The first three years of PARDYP have given rise to many findings, as documented in the papers in this volume. The five watersheds were found to have both common and individual characteristics, advantages, and problems. The work carried out to date has shown that the major issues common to many of the watersheds in the HKH include the following.

- Population issues leading to land use intensification
- Drinking and irrigation water shortages in the dry seasons
- Problems concerned with soil acidity and widespread soil nutrient deficiencies
- Soil erosion and downstream sedimentation

- Forest degradation, and fodder and fuelwood deficiencies
- The need for more land and the presence of unproductive degraded lands
- Poor agricultural productivity due to poor or non-existent support and insufficient inputs
- Gender inequities and socioeconomic problems due to resource deficiencies and/or mismanagement
- General lack of information—for example, about new and indigenous techniques, appropriate modern farming methods and resource management, and marketing opportunities

The implications of the first three years of PARDYP include the following.

- The hydrometeorological and sedimentation databases require data from several more years of field monitoring to make a significantly useful scientific contribution. These unique databases will be of great benefit in the future to all those concerned in the fields of hydropower, dam design, and flood risk.
- In PARDYP Phase I, sufficient studies have been undertaken to identify a large number of potential initiatives to combat some of the key resource problems affecting the watersheds under study. However, changes do not happen overnight and more time is required to ensure that these initiatives are appropriate in the long term in terms of technology, socioeconomics, community involvement, and equity.
- Much has been achieved in the first three years and a solid foundation constructed, but much still remains to be achieved

A Planning Workshop for Phase II was held in May 1999, and the three major donors have approved the funding of a further three-year Phase II. This extension to the PARDYP project presents many opportunities, and some important recommendations on management of the middle mountains of the HKH can be expected within the coming three years.

- Forest degradation, and fodder and fuelwood deficiencies
- The need for more land and the presence of large [illegible]
- Poor agricultural productivity and poor government support and extension inputs
- [illegible] management
- General lack of information—for example, about new and indigenous techniques, appropriate modern farming methods and resource management, and harnessing [illegible]

methodologies were developed for [illegible] permitted in order that the method used [illegible] to the particular watershed [illegible] and management.

The achievements of the first three years of PARDYP include the following:

- The hydrometeorological and sedimentation databases require data from several more years of field monitoring to make a significantly useful scientific contribution. These unique databases will be of great benefit in the future to all those concerned in the fields of hydropower, dam design, and flood risk.
- In PARDYP phase I sufficient studies have been undertaken to identify a large number of potential initiatives to combat some of the key resource problems affecting the watersheds under study. However, a longer [illegible] are required to ensure that these initiatives are appropriate in the long term, in terms of technology, socioeconomics, community involvement, and equity.
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Acknowledgements

Many people in the five watersheds and in the many partner institutions in the HKH, and in Singapore, Canada, and Switzerland contributed to the People and Resource Dynamics Project (PARDYP) in its first three years.

In particular, for their continuing and enthusiastic support, special thanks go to Professor Hans Schreier and Dr. Sandra Brown from the University of British Columbia; and Dr. Rolf Weingartner, Dr. Thomas Hofer, and Mr. Juerg Merz from the University of Bern.

Sincere thanks for their support, stimulus, and enthusiasm go to the associated members of the three funding organisations, in particular:

- from the Swiss Agency for Development and Cooperation, Mr Felix von Sury, and subsequently Mr Karl Schuler, in Kathmandu, and Mr. Peter Maag, Ms. Christine Grieder, and Dr. Carmen Thonnissen in Bern;

- from the International Development Research Centre, Dr John Graham, Dr Ronnie Vernooy, and Mr Jean Marc Fleury;

- and from the International Centre for Integrated Mountain Development, Mr Egbert Pelinck (the Director General), Dr Mahesh Banskota (the Deputy Director General), and the many other collaborators from ICIMOD who provided both professional and logistical support.

The papers within these proceedings reflect the breadth of study that has taken place during the first three years of PARDYP, as well as the discussions and deliberations that took place at the Final Workshop in Baoshan in May 1999. Three Annual Workshops were held during the first phase of PARDYP—at Kathmandu in Nepal in 1997, at Almora in India in 1998, and at Baoshan in China in 1999—and special thanks go to all those who spent considerable time and energy in organising these yearly meetings.

The papers also represent a culmination of much hard work in sometimes difficult conditions by many many people. These persons include many of the local residents and farmers of the five watersheds who have participated in the project as, for example, station readers, site monitors, trial managers, advisors, village organisers, group leaders, extension agents, assistants, and informants. Certain members of the line agencies and local NGOs in the four countries have also contributed considerably to the success of the research and development activities.

Many students from several countries have also played major roles for short periods of time over the last three years—students from China, India, Nepal, Pakistan, Canada, and Switzerland have all contributed significantly to the research studies on the ground.

Last but not least, the work has been carried out and moved on by the substantial efforts of the Country Coordinators and the project field teams in the four countries:

- Professor Xu Jianchu and his team from the Kunming Institute of Botany in China,
- Dr Bhagwati P. Kothyari and his team from the GB Pant Institute for Himalayan Environment and Development in India,
- Mr Pravakar Bikram Shah and his team at ICIMOD in Nepal, and
- Mr Hakim Shah and his team from the Pakistan Forest Institute.

All of the Country Coordinators have been provided with the much valued support of the Directors of their respective institutions—special thanks are therefore due to Dr Lok Man S. Palni of the GB Pant Institute in Almora, Mr Raja Mohammed Ashfaque at the Pakistan Forest Institute, and Dr Hao Xiaojiang at the Kunming Institute of Botany.

List of Acronyms and Abbreviations

µS/cm	micro sievert per cm
AAO	ammonium oxalate extraction
ADB/N	Agricultural Development Bank, Nepal
AEPC	Alternate Energy Promotion Centre
BHQ	Block Headquarters
BNWCS	Bhabisya Nirman Women Cooperative Society
CBD	citric bicarbonate—dithionite extraction
CBO	community based organisation
CEC	cation exchange capacity
CIP	Centro Internacional de la Papa
cmol/kg	centimoles per kilogram
CPR	common property resource
CRT/N	Centre for Rural Technology, Nepal
dbh	diameter at breast height
DDC	District Development Committee
DFO	District Forest Office
DFO	Divisional Forest Officer/District Forest Office
DHM	Department of Hydrology and Meteorology of Nepal
DoF	Department of Forestry
DSCWM	Department of Soil Conservation and Water Management
ECOSOC	Economic and Social Council of the United Nations
FAO	Food and Agriculture Organization (UN)
GIS	geographic information systems
GJ	Giga Joules
GPS	global positioning system

HH	households
HKH	Hindu Kush-Himalayas
ICIMOD	International Centre for Integrated Mountain Development
ICS	improved cooking stove
IDRC	International Development Research Centre
IST	Indian Standard Time
IUCN	International Union for the Conservation of Nature
IVI	importance value index
IYM	International Year of (the) Mountains
JCS	Jansachetan Cooperative Society
JKW	Jhikhu Khola Watershed
LRMP	Land Resource Mapping Project
masl	metres above (mean) sea level
MWh	Megawatt hour
NA	not applicable/not available
NARC	National Agriculture Research Council
NEA	Nepal Electricity Authority
NGO	non government organisation
NRs	Nepalese Rupees
PARDYP	People and Resource Dynamics Project
PET	potential evapotranspiration
PRA	participatory rural appraisal
REDP	Rural Energy Development Programme
RET	renewable energy technology
RRA	rapid rural appraisal
R&D	research and development
SC	scheduled caste
SCG	Savings and Credit Group
SDC	Swiss Development Cooperation
SHS	solar home system
TCDC	Technical Cooperation Among Developing Countries
TLU	tropical livestock units
TMI	The Mountain Institute
UN	United Nations
UNCED	The United Nations Conference on Environment and Development
UNDP	United Nations Development Programme

VDC	village development committee
WECS	Water and Energy Commission Secretariat
WUG	women's user group
YKW	Yarsha Khola Watershed

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Introduction

[illegible] has been [illegible] one in [illegible] shown in

[illegible] to growing [illegible] of the [illegible] mountains of the [illegible] ... mation of the mountain farmer, the [illegible] availability of water, [illegible] and forest degradation and declining soil fertility, and the questions [illegible] ... atural resource base exceeding the natural carrying and regeneration

[illegible] from two IDRC-funded ICIMOD projects

[illegible] 'Mountain Resource Management Project' (1989 to [illegible] ... [illegible] resource dynamic studies in the Jhikhu Khola [illegible] ... Rehabilitation of Degraded Lands in Mountain [illegible] ... [illegible] 1996), which [illegible] ... Nepal, and [illegible] and involved the rehabilitation and [illegible] ... [illegible] denuded [illegible] slopes of the [illegible]

[illegible] experience and knowledge [illegible] ... two projects—viz. geographical generalisations are not [illegible] ... [illegible] from replicated tests and trials are available, water is as important [illegible]

The Project

'People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas', now more commonly known as PARDYP, is a research for development project that has been operating for three years in five watersheds across the HKH—one watershed in China, one in India, two in Nepal, and one in Pakistan. The locations of the five watersheds are shown in Figure 1.

PARDYP was launched in response to growing concerns regarding the pressures on the resources and the people in the middle mountains of the HKH. Of special concern were, and still are, the marginalisation of the mountain farmer, the use and availability of water, issues appertaining to land and forest degradation and declining soil fertility, and the question: "Are the stresses on the natural resource base exceeding the natural carrying and regeneration capacity?"

PARDYP evolved from two IDRC-funded ICIMOD projects:

- the 7 year 'Mountain Resource Management Project' (1989 to 1996) which undertook resource dynamic studies in the Jhikhu Khola watershed of Nepal, and
- the 'Rehabilitation of Degraded Lands in Mountain Ecosystems Project' (1992-1996), which was undertaken by research institutes in four countries (China, India, Nepal, and Pakistan), and involved the rehabilitation and re-greening of small patches of degraded and denuded land on valley slopes of the HKH.

Much experience and knowledge was gained and several important lessons were learnt from these two projects—viz. geographical generalisations are not appropriate unless long-term results from replicated tests and trials are available, water is as important as soils in terms of both dynamics and sustainability, the institutional and policy setting must be supportive to sustainable development, and common methodologies and scientific rigour are of key importance in monitoring the biophysical parameters at all sites.

The outcome of the successes of these projects was a Planning Workshop in March 1996 at which gathering the PARDYP project was evolved—to be funded by SDC, IDRC, and ICIMOD. Agreements between SDC and ICIMOD, and IDRC and ICIMOD were signed in late 1996.

PARDYP was designed as an integrated research for development project concerned with natural resource dynamics and degradation processes in the middle mountains of the Hindu Kush-Himalayas (HKH). Information was to be gathered in a harmonized fashion on various physical and socioeconomic factors related to natural resources in five different watersheds in four countries of the HKH. The watersheds would represent a number of the different physical and socioeconomic situations in the region. Appropriate techniques for measurement would be developed where necessary, and the approach to data collection and information synthesis harmonized in such a way that the results could be used to develop a picture of the situation in the HKH mid hills region as a whole, to provide a basic

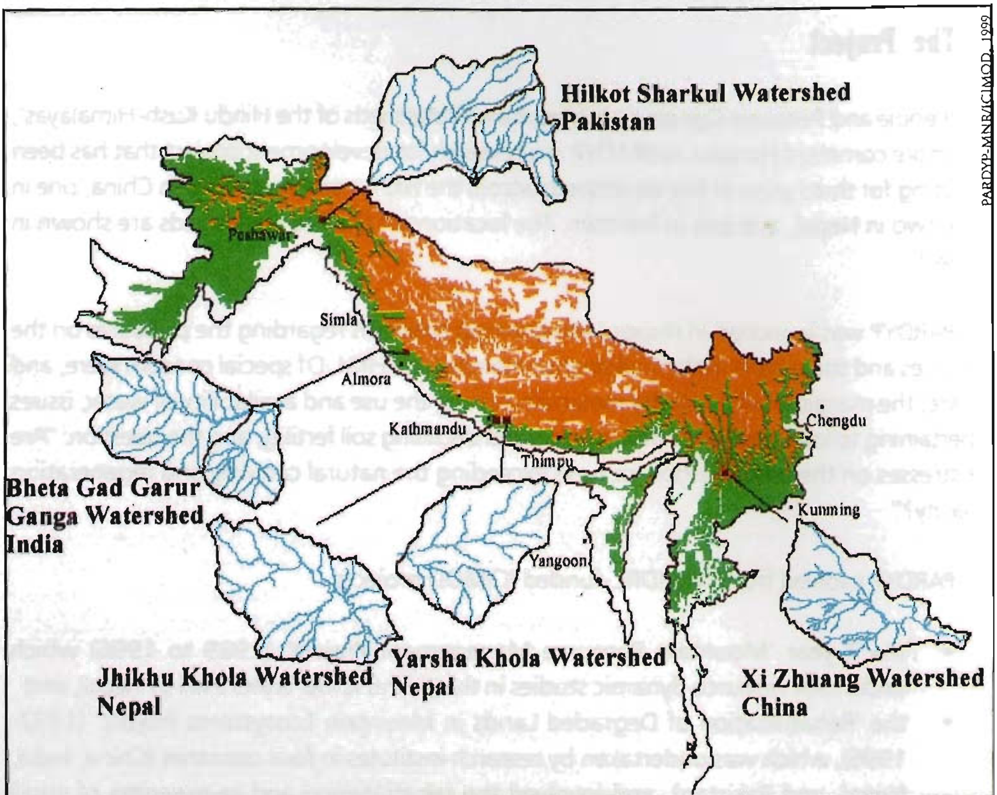

Figure 1: **Location of the Five Watersheds in the HKH Region**

understanding of the nature resource degradation processes, and to develop and recommend proven strategies and programmes appropriate to the greater part of the mid hill areas of the HKH for rehabilitation and improved management.

The key goals and objectives for Phase 1 of PARDYP, defined by the planning workshop participants, are shown in Table 1. There were seven components each with a specific objective:

- water balance and sedimentation,
- soil fertility improvement and soil erosion control,
- socioeconomic factors in terms of resource management,
- natural resource management strategies,
- capacity building of project partners,
- dissemination of knowledge, and
- effective and efficient management.

The modus operandi of the project was as follows:

- establishment of national institutional teams to undertake the prescribed activities along with required national partners in selected middle mountain watersheds in four countries,

Table 1: **The Objectives of PARDYP Phase 1**

Goal

To further improve the understanding of the environmental and socioeconomic processes associated with the degradation and rehabilitation of mountain ecosystems, and to generate wider adoption and adaptation of proposed solutions by stakeholders in the HKH

Project Objective

To provide a basic understanding of natural resources' degradation processes and to recommend proven strategies and programmes for community and farm-based prevention of degradation and rehabilitation of natural resources in the HKH region

Specific Objectives

- to generate relevant and representative information about, and technologies for measuring, water balance and sediment transport related to degradation on a watershed basis
- to identify technologies and strategies to improve soil fertility and to control erosion and degradation processes in a farming system approach
- to generate socioeconomic information on resource management and degradation
- to systematically apply community-based participatory generation, testing, and evaluation of natural resources' management strategies and technology
- to strengthen the capacity of project partners
- to make accessible to stakeholders relevant information on project outputs
- to effectively and efficiently manage the project as a regional collaborative R & D undertaking

Important Aspects

- Research agenda of the original IDRC-ICIMOD projects to be widened
- New local and non-local partners to provide specific contributions
- Wherever possible, all activities to be implemented under a unified methodology
- A common framework for socioeconomic and biophysical interventions to be developed over the long term and implemented systematically
- Field research and monitoring systems to be carefully designed and established for long-term data generation
- Well-defined watersheds to be used as the study sites
- A second watershed to be included in Nepal (Yarsha Khola) to validate some of the results from Jhikhu Khola
- Study team members to be exposed to participatory data collection and action research through appropriate training programmes

- establishment of research and community networks,
- linkages with appropriate local partners,
- common and rigorous methodologies wherever appropriate,
- on and off-farm participatory action research,
- capacity building of project staff and collaborative training of local farmers,
- specialist expertise and consultancy services from Canadian and Swiss universities,
- administered from ICIMOD in Kathmandu through a Regional Coordinator and four Country Coordinators.

The expected impacts were

- an increase in knowledge about the causes and results of degradation in the HKH in terms of a broad range of biophysical and socioeconomic aspects;
- identification of appropriate technologies to combat degradation and promote improved resource management across the region;
- the establishment of a regional database on key aspects of both the dynamics and management of middle mountain watersheds; and
- improved capacity of both institutional and watershed partners in many fields—from the undertaking of research to participatory management of natural resources.

Phase I of PARDYP began on October 1st 1996 and ended on September 30th 1999. Through cooperative rural participation, Phase I has been involved in research and investigations within the fields of hydrology and meteorology, water availability and management, soil erosion and fertility, on-farm and off-farm conservation and rehabilitation, community forestry, agronomic and horticultural initiatives, and social and economic issues. The main characteristics of the five watersheds in which PARDYP Phase I was active are summarised in Table 2.

This document constitutes some of the results and findings of the activities carried out after two complete monsoon seasons, and is based on the papers presented at the Final PARDYP Phase I Workshop held in Baoshan, China, in May 1999.

Since the project started, the dynamics of the middle mountain situation have accelerated. Populations have continued to increase; out-migration of the young has continued in some watersheds, in-migration has swelled numbers in others; and farming systems and society have continued to develop and transform in terms of cash crops produced, the use and misuse of agrochemicals, the need for and extraction of water, aspirations of the young and middle aged, and the need for cash. As a number of the following papers report, new burdens are being placed on both the residents of the middle mountain watersheds, especially the women, and on the environment.

The thinking and reasons behind PARDYP have strengthened not diminished in recent years, and as a result of this the three donor agencies that supported PARDYP during Phase have agreed to fund a continuation of the project to the end of 2002. New components in Phase II include more emphasis on farmer and community-led research, gender and equity issues, and stakeholder participation in planning, undertaking, monitoring, and evaluating the programmes.

The Achievements of PARDYP Phase I

Many of the research programmes and development initiatives undertaken during Phase I are described in detail in the papers included in this document. The main achievements of PARDYP's first three years are summarised very briefly below.

- Establishment of core field R&D teams, and of strong links with national institutions and groups
- Upgrading of skills of the young scientists and technicians through training and experience in many different fields
- Establishment and subsequent upgrading of the basic biophysical research networks in the five watersheds
- Continuous monitoring at 27 hydrological stations and 43 meteorological sites, and recording of data by trained watershed residents and project employees in the five watersheds
- On-going establishment of hydrometeorological databases, production of the Yearbooks for 1997 to1999, and initial analysis of the results
- Collection, recording and analysis of erosion plot data relating to runoff and soil loss from 23 sites under 7 different types of land use
- Training of field teams and local residents in PRA in all five watersheds, participatory field exercises in all countries, and subsequent documentation of farmer and community needs and aspirations
- Collection of much basic social and biophysical data through investigation and survey, and subsequent integration through use of a GIS—for example, in the fields of household socioeconomics, marketing, demographics, gender, geology, water chemistry, soil fertility and nutrient dynamics, land use, and community forestry
- Further generation of awareness and understanding of the project and its objectives in the watershed communities, and at local government offices, NGOs and relevant projects
- Beginnings of a more farmer-orientated approach to research for development
- Establishment of a workable management, administrative, and financial system for a regional research and development project working in five watersheds and four countries

Small but significant steps forward have been made in certain areas of research for development that are of direct benefit to people, and in policy change at the local level. Examples include:

- community forestry and social fencing in the Bheta Gad watershed, India;
- energy studies and policy change in the Yarsha Khola watershed, Nepal;
- significant gender studies in the Nepal, India, and China watersheds;

Table 2: **Summary of Watershed Characteristics**

	XiZhuang (China)	Bheta Gad Garur Ganga (India)	Jhikhu Khola (Nepal)	Yarsha Khola (Nepal)	Hilkot-Sharkul (Pakistan)	Total
Physiography						
Total area (ha)	3,456	8,481	11,141	5,338	5,230	
Elevation range (masl)	1700-3075	1090-2520	800-2200	1000-3030	1448-2911	
Climate	Wet and dry seasonal variation	Marked wet and dry seasonal variation	Humid sub-tropical to warm temperate	Humid sub-tropical to warm temperate	Humid sub-tropical to cool temperate	
Dominant Geology	Limestone and sandstone	Schists and Gneiss	Mica schist and calcareous schist	Gneiss and slate+graphitic schist	-	
Monitoring						
Meteorology	11	5	10	11	6	43
Hydrology	5	6	5	6	5	27
Erosion plots	6	4	6	4	3	23
Rehabilitation	3	2	4	4	1	14
Population						
Total population	4,016 (1997)	14,524 (1998)	48,728 (1996)	20,620 (1996)	11,322 (1998)	
Population density (people/sq.km.)	116	171	437	386	243	
Average family size	4	7	6	5	11	
Dominant ethnicity	Han Chinese	Brahmin, Rajputs, Scheduled castes	Brahmin, Chettri, Tamang, Danuwar	Brahmin, Chettri, Tamang,	Gujar, Swati, Syeds	

Table 2: **Summary of Watershed Characteristics** (cont'd)

	XiZhuang (China)	Bheta Gad Garur Ganga (India)	Jhikhu Khola (Nepal)	Yarsha Khola (Nepal)	Hilkot-Sharkul (Pakistan)	Total
Land use						
Land tenure	All land owned by the state	All farmland privately owned	All farmland privately owned	All farmland privately owned	All farmland privately owned	
Land use types in per cent	Forest 41 Grass 32 Rainfed 16 Tea garden 5 Paddy 2 Shrub 1 Settlement 1 Other 2	*Khet* 15 *Bari* 27 Forest 56 Barren 1 Other 1	*Khet* 17 *Bari* 38 Forest 30 Grass 6 Shrub 7 Other 3	*Khet* 14 *Bari* 37 Forest 32 Grass 6 Shrub 5 Other 6	Forest 19 Agriculture 51 Other 30	
Farming system						
Major cash crops	tea, tobacco, fruit	winter vegetables, fruit, tea, fodder	potatoes, tomato, rice, fruit, vegetables	seed potatoes, some fruit	fruit, fodder	
Main staple crops	maize, wheat, beans, potato, rice	maize, rice, wheat	rice, maize, wheat, potato, millet	maize, rice, millet, potatoes, wheat	wheat, maize, rice	

Khet = irrigated rice land; *Bari* = rainfed cultivated land

- innovative agronomic initiatives in Nepal (e.g., zero-tillage in winter wheat, alternative systems of pest management);
- fresh historical perspectives on development in China;
- a start on water harvesting investigations in Nepal and India;
- new soil fertility management studies in terms of biofertiliser use in India, and nutrient dynamics in Nepal;
- training in compost management in India and Nepal; and
- efforts at increasing cash generation potential for farmers through market studies, use of polyhouses, vegetable production, and on-farm introduction of new varieties in all four countries.

The Workshop

The Workshop began on March 2nd and closed on March 5th 1999, and was attended by those listed in Table 3. The participants came from nine countries. The workshop was held in the Lan Du Hotel in Baoshan, Yunnan Province, China.

Table 3: **Participants at the Final Phase I Workshop in Baoshan, Yunnan Province, China**

From the Indian Watershed–*GB Pant Institute of Himalayan Environment and Development (GBPIHED)*	
Dr Bhagwati P. Kothyari	Country Coordinator
Mr Sanjeev Bhuchar	Social Forester
From the Pakistani Watershed—*Pakistan Forest Institute (PFI)*	
Mr Mohammed Khan	Country Coordinator
Ms Mamoona Malik	Social Forester/PRA/Gender
From the Chinese Watershed—*Kunming Institute of Botany (KIB)*	
Professor Xu Jianchu	Country Coordinator and Resource Management, KIB
Mr Yang Yongping	Land Use Specialist and Socioeconomist, KIB
Mr Wang Yuhua	Computer Specialist and Database Manager, KIB
Mr Gao Fu	Erosion Plots, KIB
Ms Yang Lixin	Social Forester, KIB
Ms Ai Xihui	GIS Specialist, KIB
Ms Qian Jie	Gender Issues and Workshop Secretary, KIB
Prof. Yang Qixiu	Ecologist, Chengdu Institute of Biology
Mr Sha Liqing	Soils Specialist, Xishuangbanna Tropical Botanic Garden
Mr Fan Lizhang	Meteorologist, Yunnan Climate Centre
Mr Lin Hai	Meteorologist, Yunnan Climate Centre
Mr Li Jinghong	Hydrologist, Baoshan Hydrology Bureau
Ms Ma Xing	Hydrologist, Baoshan Hydrology Bureau
Mr Cheng Deai	Forester, Baoshan Forest Bureau

Table 3: Participants at the Final Phase I Workshop in Baoshan, Yunnan Province, China (cont'd)

From the Nepalese Watersheds—*International Centre for Integrated Mountain Development (ICIMOD)*	
Mr Pravakar B. Shah	Country Coordinator
Mr Gopal Nakarmi	Hydro-Geologist
Mr Bhuban Shrestha	GIS, Land Use Specialist, Social Issues
Mr Prem Neupane	Agronomist/Site Supervisor
From His Majesty's Government/Nepal	
Mr Bal K. Khanal	Deputy Director General, Planning Division, Department of Forest
Mr Prakhash Mathema	Head Research Division, Department of Soil Conservation and Watershed Management
From ICIMOD	
Mr Richard Allen	PARDYP Project Coordinator
Dr Pradeep Tulachan	Farming Systems and Socioeconomist
From the University of Bern (UoB)	
Dr Rolf Weingartner	Hydrometeorology Consultant to PARDYP
Mr Juerg Merz	Research Associate, Hydrology
From the University of British Columbia (UBC)	
Professor Hans Schreier	Land Resources Consultant to PARDYP
Dr Sandra Brown	Land Resources Consultant to PARDYP
From FAO, Rome	
Dr Thomas Hofer	Officer, Forest Department, Forest Resources Division, FAO
From ICIMOD	
Mr Egbert Pelinck	Director General of ICIMOD
Dr Narpat S. Jodha	Policy Analyst and Review Mission member
From SDC	
Ms Christine Greider	Deputy Head Agricultural Service, SDC, and Review Mission member
From IDRC	
Dr John Graham	Senior Regional Program Officer, IDRC-Singapore
Dr Brian Carson	Team Leader of the Review Mission
Mr Ronnie Vernooy	Senior Program Officer, IDRC-Ottawa
Mr Jean Marc Fleury	Publications Department, IDRC-Ottawa

There were five main objectives for the workshop:

- to review the activities and highlight the achievements of the first 2½ years of PARDYP in the four participating countries;
- to finalise the draft work programme for 1999;
- to provide guidance and assistance to the collaborating teams where necessary;
- to assist the three person PARDYP Review Mission in their task of monitoring and evaluation; and
- to look forward to PARDYP Phase II and plan accordingly.

The first two days consisted of presentations of the papers from representatives of the five watersheds and their research associates. The middle day was spent visiting the XiZhuang watershed, observing the research sites that had been established, meeting and lunching with the people of the watershed, and examining the developments that had taken place during the first two and a half years of PARDYP.

During days four and five, the need for a second phase was examined together with the options, the modus operandi, and the direction of future research programmes. This was the start of the planning process for PARDYP Phase II; this process was continued at the Phase II Planning Workshop, held in Kathmandu in May 1999, and culminated in the submission of the Phase II PARDYP Project Proposal submitted by ICIMOD to SDC and IDRC in September 1999.

The Papers

The papers are presented here in four main sections comprising the broad thematic schemes of the people and their relationships to their environment (Part 1), the forests (Part 2), the hydrometeorological, sediment, and water aspects (Part 3), and the geological, and soil dynamic issues (Part 4). A discussion of the relationship to Chapter 13 of Agenda 21 and a concluding paper complete the proceedings.

Part One

The People and Their Resources

The Use of Socioeconomic Indicators in Resource Management

Sandra Brown
Institute for Resources and Environment, University of British Columbia
Vancouver, Canada

Abstract

Socioeconomic indicators are an important component of understanding resource management, the constraints faced by farmers, and why the status of natural resources is changing. Within the middle mountains of Nepal, social, economic, and cultural factors such as population growth, ethnic traditions, land ownership, and farm economics influence how resources are managed and ultimately effect degradation. Household surveys were used to compile information from farmers about their socioeconomic conditions, including land ownership, food security, and agricultural assets. Farm gross margins were calculated to compare the economic status of households growing a variety of crops. On an individual crop basis, tomatoes and potatoes (both cash crops) were the most profitable, and households that included a cash crop in their rotation typically displayed the highest gross margins. Eighty-three percent of households growing at least one cash crop in their rotation had gross margins of greater than CDN$100[1] per year, while 36 per cent of households not growing vegetables had negative gross margins. Food security was also related to the amount of cultivated land owned by a household and to gross margins. The economic well-being of households is unevenly distributed and linked to land ownership and market-oriented production.

Introduction

To understand why farmers choose different management and cultivation practices, it is necessary to appreciate the intricacies of the system within which they are operating. Social and economic factors such as population growth, land distribution, agricultural assets, and farm income will influence how resources are managed and how they are distributed within communities. Degradation and the status of natural resources can be assessed by conducting semi-structured surveys among community members within watersheds. Baseline socioeconomic data can be compiled and analysed to characterise farm households and provide indicators, which may then be linked to the status of the biophysical resource use.

This study focused on determining population density and growth; ethnic distribution; land and livestock holdings, and how they influence food security; agricultural assets; and farm gross margins. The latter is a good indicator of poverty and reflects the quality of the resource system.

1 CDN$ 1 = NRs 47, US$ 1 = NRs 68 in July 1999

Household Surveys

Detailed surveys were conducted with 85 households in the Jhikhu Khola watershed (Figure 2) and the results compiled to provide information about the constraints on farmers (social, economic, and physical) and their aspirations (individual, household and village-wide). (The selection criteria are given in Schreier and Shah in this volume.) A semi-structured interviewing approach was used. Simultaneous and separate man/woman farmer interviews were conducted to incorporate a cross-check system and to compare the perceptions and problems of both men and women farmers. In most cases, the interview was conducted at farmers' homes with the women (female Nepali interviewer and woman farmer) holding their discussion indoors while the men (male Nepali interviewer and man farmer) talked out of earshot in the courtyard. Information on crop production, livestock operations, forest products, sufficiency status, ethnic distribution, and off-farm employment were compiled and analysed to evaluate household access to resources and indices of poverty.

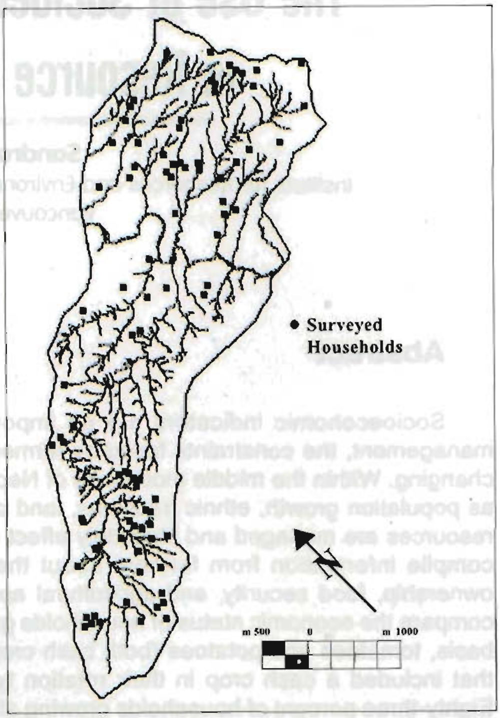

Figure 2: **Location of Households Surveyed, Bela Subcatchment, Jhikhu Khola Watershed**

Population growth, land distribution, ethnic distribution, and livestock holdings provide a good basic set of poverty indicators. Land and livestock comprise the main agricultural assets. Farm gross margins were determined from production information (crops grown, total production, and inputs) and together with agricultural assets were compared to food security.

Population Growth

To evaluate the current population and recent trends within the study area, a survey of constructed houses was undertaken for 1972, 1990, and 1995. The number of houses identified on 1972 and 1990 aerial photographs were counted and compared to the number of houses observed in the field in 1995. Population numbers were calculated from the number of houses, and the average family size (6.7 people per household) determined from household surveys. Figure 3 shows the recent changes in the number of houses and the calculated population. The number of houses in the study area increased from 1,104 in 1972 to 1,723 in 1995. The average population growth was estimated at 1.8 per cent per annum between 1972 and 1990 and 2.6 per cent per annum between 1990 and 1995. The recent large increase is due to both population growth and immigration. These high population growth rates are a concern for resource degradation as all 'good' agricultural land is already under intensive production, forest resources are already limited, and agriculture is being forced to expand onto steep marginal upland slopes.

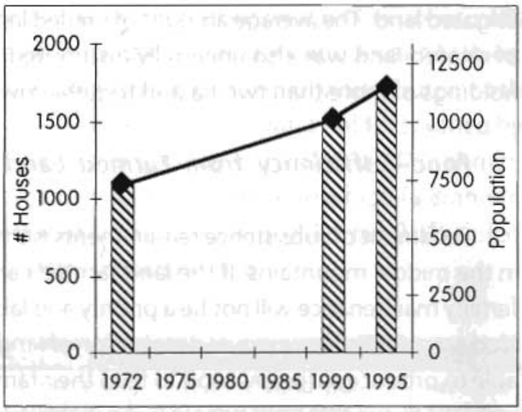

Figure 3: **Bela Population Dynamics 1972-1995**

Land Distribution

Historical land tenure policies have shaped agricultural development in Nepal. The feudal land tenure system (abolished by the 1957 Birta Abolition Act) resulted in a small minority of larger landowners possessing a substantial portion of the arable land. Land registration, implemented in 1963, encouraged the private registration of previously public lands through low tax rates, and resulted in increased pressure on the remaining public forest and rangelands. The Forest Nationalisation Act of 1957 probably accelerated deforestation as land with trees on it could not be registered as private land. The 1964 Nepali Lands Act strove to improve the status of land tenure for small-scale farmers by establishing a ceiling on land holdings and providing rights to tenants, but the programme has been largely ineffective (Seddon 1987; Regmi 1976).

Land ownership within the agrarian economy of the study area provides a major source of income, and inequity in land distribution translates to economic disparity. Farmers with limited access to land or poor quality land will have little economic incentive or ability to invest in soil fertility management (Blaikie *et al*. 1980). In the Bela household survey (n=85) the median land holding per household was 0.92 ha (1 ha = 19.7 *ropani*), but the amount of land varied significantly across different size categories (Figure 4). Land ownership was unevenly distributed with 53 per cent of the households owning only 25 per cent of the total agricultural land area (total holdings per household less than1 ha). Large landowners (holdings >2 ha) made up 15 per cent of households, but owned 36 per cent of the agricultural land. Two families owned no land. The average amount of irrigated land was 0.24 ha per household, but 24 per cent of households owned no irrigated land. Fifteen per cent of households had larger irrigated holdings (>0.5 ha) and owned 46 per cent of the

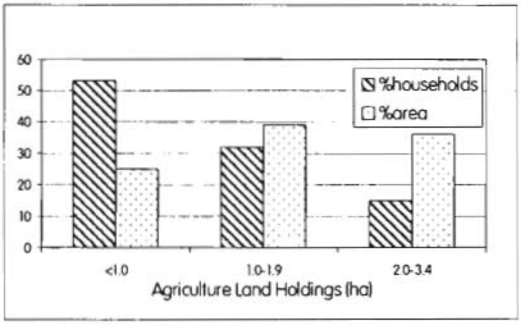

Figure 4: **Land Holdings in the Bela Subcatchment**

irrigated land. The average amount of rainfed land per household was 0.81 ha but ownership of rainfed land was also unequally distributed. Twelve per cent of households had rainfed holdings of more than two ha and together owned 32 per cent of the rainfed land.

Food–Sufficiency from Farmed Land

Fulfilment of subsistence requirements is the primary objective of the majority of farmers in the middle mountains. If the land farmed cannot provide a household's basic needs, soil fertility maintenance will not be a priority and labour will be diverted to off-farm employment (Seddon 1987). The unequal distribution of land suggests that some households may not be able to produce sufficient food to feed their families. As an indication of the amount of land required to support a household living in the Bela region, farmers were asked: "Does the land that you farm generate enough food and income to meet your family's basic needs?" Fifty-three percent of the households surveyed reported that the land they farmed was enough, while 13 per cent responded that the land they farmed was insufficient. Thirty-four percent of the responses from male and female farmers within one household were contradictory suggesting a marginal sufficiency status. The ratio of the land farmed to the number of people in a household for sufficient and non-sufficient households provides a rough estimate of the amount of land required to support each individual (Table 4). Among the households reporting that the land they farmed was not enough, the average ratio of land owned to the number of people was 0.13 ha per person, of which 0.02 ha per person was irrigated land. Among the households reporting that their land provided enough food and income, the average ratio was 0.20 ha per person, of which 0.05 ha was irrigated, more than double the amount of irrigated land held by the 'insufficient' group. In the Bela region, roughly 0.15 ha of land (0.03 ha irrigated and 0.12 ha rainfed) is required as a minimum for every person a household hopes to feed.

Table 4: **Per Capita Availability of Agricultural Land**

Sufficient	n	Per Capita Land Ownership (ha per person)		
		Cultivated Land	Irrigated Land	Rainfed Land
No	11	0.13	0.02	0.11
Marginal	29	0.15	0.03	0.12
Yes	45	0.20	0.05	0.15

Ethnic Distribution

The bulk of households were agriculturalists, but mercantile occupations were strong within some groups. Brahmins (priest caste) are the highest in the caste hierarchy and comprised 54 per cent of the sample. Chhetris are ranked second in the hierarchy and comprised six per cent of the sample. Agriculturalists and traders, who include indigenous tribal hill groups such as Newars, Danuwars, and Magars, comprised 26 per cent of the sample. Service groups made up six per cent, and Tamangs (a Tibeto-Burman community) eight per cent of the sample. Caste affiliation and ethnic distribution generally reflect the class structure and influence access to resources. High caste groups tend to be larger landowners, while low caste households have the poorest access to arable land. The relationship between caste and land ownership is related to historic land tenure policy, with the state traditionally granting land to members of the ruling class and local notables. However, class relations are dynamic and land ownership was unequally distributed both across caste/ethnic groups and within each group (Table 5). Median land holdings varied by caste from 0 to 0.31 ha of irrigated land, and 0.2 to 1.42 ha of rainfed land. Brahmin, Newar, and Tamang families had the largest median holdings. The sample high (a Brahmin household) owned 1.12 ha (22 *ropani*) of irrigated land and 2.24 ha (44 *ropani*) of rainfed land, while two households (Danuwar and Chhetri) owned no land.

Table 5: **Land Ownership by Caste/Ethnic Group**

Caste	Sample No.	Irrigated Land per Household (ha)			Percent Owning Irrigated	Rainfed Land per Household (ha)			Per Cent Owning Rainfed
		median	min.	max.		median	min.	max.	
Brahmin	46	0.25	0	1.12	85	0.81	0.10	2.54	100
Newar	13	0.25	0	0.76	77	0.61	0.25	1.07	100
Tamang	7	0.31	0	0.81	71	0.41	0.15	2.14	100
Danuwar	9	0.05	0	0.20	67	0.20	0	1.02	89
Chhetri	5	0	0	0	0	0.46	0	0.71	90
Others	5	0.13	0.05	0.20	100	1.42	0.66	2.14	100
Median	85	0.20	0	1.12	76	0.71	0	2.54	94

Role of Livestock

Livestock, via the production of manure, are a major contributor to traditional soil management practices and through dairy provide an important source of income. Figure 5 shows the changes in the livestock holdings of surveyed farmers in the Baluwa region (n=27) from 1989 to 1996. The number of calves for both cattle and buffalo and the number of chickens decreased from 1989 to 1996, while the number of female cattle and buffalo

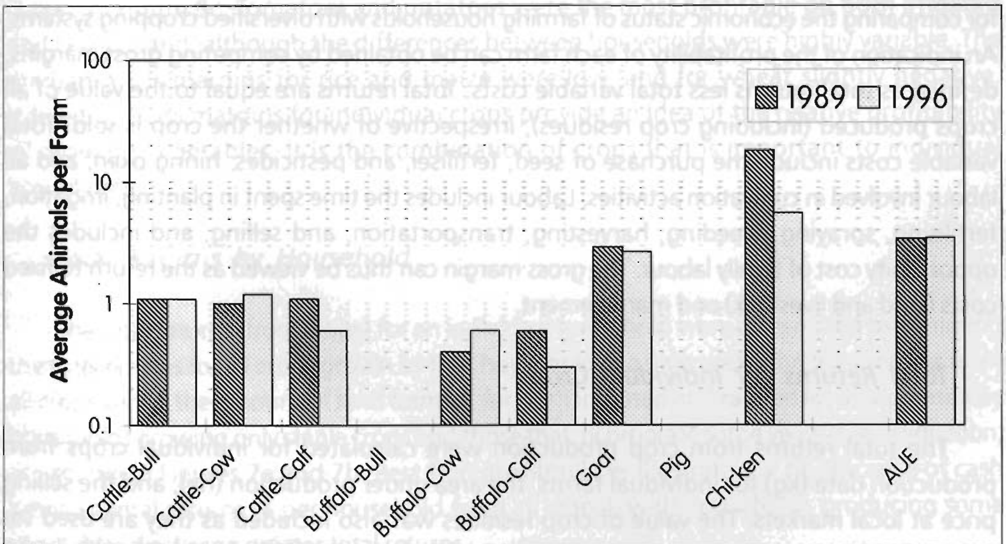

Figure 5: **Livestock Holding Dynamics in Baluwa**

increased slightly. The increase in female buffalo per household was related to the establishment of a local dairy collection centre that promotes the sale of milk. The number of TLUs (tropical livestock units) remained similar, however, indicating limited change in the potential nutrient supply from organic sources.

Agricultural Assets

The main agricultural assets of farmers in the region are land and livestock. Local land values differentiate land on the basis of quality, with poor rainfed land valued as low as CDN$ 4,700 per ha and good quality irrigated land valued at up to CDN$ 56,775 per ha. Average prices for rainfed (CDN$ 9,462 per ha) and irrigated (CDN$ 28,386 per ha) land thus provide a weighting mechanism to sum total land holdings in a manner which reflects not only value but production potential. Land values are summarised in Table 6. In general, the land values should be considered as rough estimates. The median land holding was valued at CDN$ 5,776 for irrigated and CDN$ 6,734 for rainfed land per household. While irrigated holdings accounted for less than 25 per cent of the land owned on an area basis, their value made up nearly 50 per cent of the total land values.

Table 6: **Total Land Values per Household in the Study Area**

	Irrigated		Rainfed		Total	
	ha	CDN$	ha	CDN$	ha	CDN$
minimum	0	0	0	0	0	0
median	0.20	5,776	0.71	6,734	0.92	12,508
maximum	1.12	31,768	2.54	24,050	3.36	52,932

Farm Gross Margins

The relative profitability of agricultural production between farms provides a mechanism for comparing the economic status of farming households with diversified cropping systems. An indication of the profitability of each farm can be obtained by computing gross margins, defined as total returns less total variable costs. Total returns are equal to the value of all crops produced (including crop residues), irrespective of whether the crop is sold. Total variable costs include the purchase of seed, fertiliser, and pesticides; hiring oxen; and all labour involved in cultivation activities. Labour includes the time spent in planting, irrigation, fertilising, spraying, weeding, harvesting, transportation, and selling, and includes the opportunity cost of family labour. The gross margin can thus be viewed as the return to fixed costs (land and livestock) and management.

Total Returns for Individual Crops

The total returns from crop production were calculated for individual crops from production data (kg) for individual farms, the area under production (ha), and the selling price at local markets. The value of crop residues was also included as they are used for animal fodder. Crop residues were estimated from the ratio of grain to residues (e.g., 1.25 for rice) and valued at 5-10 rupees per basket (25 kg) or CDN$ 0.007 per kg. The total returns for individual crops grown under irrigated (*khet*) and dryland (*bari*) conditions are summarised in Figure 6a. On a per ha basis, the total returns were greatest for tomatoes and potatoes grown on both irrigated and rainfed fields. The median returns for tomatoes, potatoes, and wheat on irrigated fields were higher than returns from the same crops grown under rainfed conditions, indicative of the greater production potential of irrigated lands. For irrigated land, tomatoes and potatoes have the highest total returns, but rice grown during the monsoon is also an important crop as a relatively large amount of land is under rice cultivation. For rainfed land, tomatoes and maize make up the greatest proportion of total returns, reflecting the high returns per ha of tomatoes and the large area under maize cultivation.

Variable Costs for Individual Crops

The variable costs for individual crops were computed by summing the expenditures by individual farmers on seed, chemical fertiliser, pesticides, oxen, and labour. Variable costs were dominated by labour and oxen costs, and represent the opportunity costs of alternative activities. Labour costs were greatest for tomatoes and potatoes on a per ha basis, but labour inputs to rice and maize were significant on a total cost basis ($ per household). The purchase of chemical fertilisers contributed significantly to the variable costs of rice and potatoes on irrigated, and maize on rainfed, sites. The total variable costs for the dominant crops grown on irrigated and rainfed land are shown in Figure 6b. The costs were greatest for tomatoes and potatoes, and somewhat higher on irrigated fields.

Gross Margins for Individual Crops

Gross margins for the main crops grown in the study region were determined by subtracting the variable costs from the total returns for individual crops. The results are shown in Figure 6c. Tomatoes and potatoes were the most profitable on both irrigated and rainfed land, although the differences between households were highly variable. The median gross margins for rice and maize were low, and for wheat slightly negative. While the gross margins for individual crops provide an idea of the relative profitability of growing vegetables, it is the combination of crops that is important to individual households.

Total Returns by Household

The total returns (from crops) for an individual household were determined by summing the total returns for all crops grown by that household in a given year. The total returns from all crops versus the amount of land farmed, for both irrigated and rainfed land, separated by households growing only staple crops and those that incorporate some vegetable production, are shown in Figures 7a and 7b. Best fit regression lines illustrate the significance of cash crops to total returns ($ per household from all crops), with households producing some vegetables displaying greater total returns.

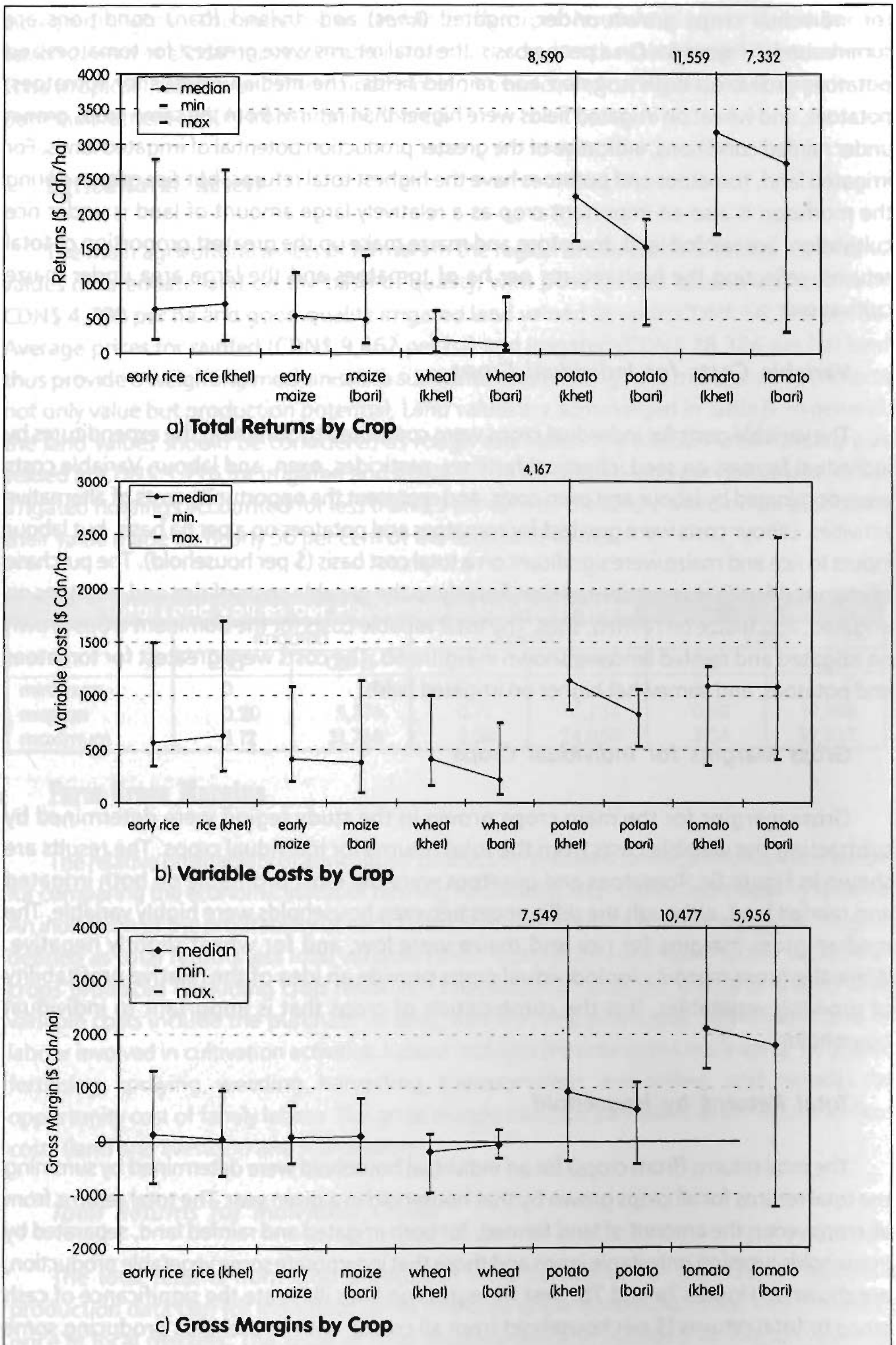

Figure 6: **Total Returns, Variable Costs and Gross Margins by Crop**

Variable Costs by Household

The variable costs for individual households were calculated by summing the costs of producing all crops grown by a household in a given year. The variable costs per household, separated by households growing only staple crops and those that incorporate some vegetable production, are shown in Figures 7c and 7d. The increase in variable costs diminished with the amount of land farmed, suggesting decreasing costs per *ropani* with larger farm size. The households reporting the highest costs did not always report the greatest returns.

Household Gross Margins

The total gross margins for a household were determined by summing the total returns less variable costs for all crops grown on all the land farmed by a household. Farm gross margins, based on all crops grown by a household, ranged from -CDN$ 566 to +CDN$ 1736 dollars per annum. Farm gross margins separated by households growing only staple crops and those that incorporate some vegetable production are shown in Figures 7e and 7f. The benefits of including vegetables within a households' farming system were significant. The highest gross margins were noted for households growing cash crops as part of their rotation, and for households with greater land holdings. Forty-one percent of the households surveyed included a cash crop in their rotation. However, households with negative gross margins included both vegetable growers and large landowners, reflecting crop failures and poor management. Of the households incorporating some vegetable production, only one had negative gross margins compared with 36 per cent of those not growing any vegetables. Eighty-three percent of the households growing at least one cash crop had gross margins greater than CDN$100 per year, while only 40 per cent of households not growing cash crops had comparable gross margins.

Gross Margins and Food Security

The gross margins for individual households provide a good indicator of economic well-being and are related to land holdings and household food security. Table 7 shows the percentage of households reporting that the land they farm is insufficient, marginal, or sufficient to meet their basic need requirements by category of household gross margin. Forty-five percent of the households reporting insufficient production had negative gross margins, while 55 and 56 per cent of marginal and sufficient households had gross margins of more than CDN$100 per year. Households that are not able to meet their basic need requirements also have the lowest per capita land ownership (Table 4), and none of these households had per capita gross margins above CDN$ 50 per year. While this indicator provides a good measure of household level economic well-being, the data requirements are high and selective use of the indicator is recommended. Data on labour requirements are tenuous, and the yield data reported by farmers need to be verified with quantitative crop cut data.

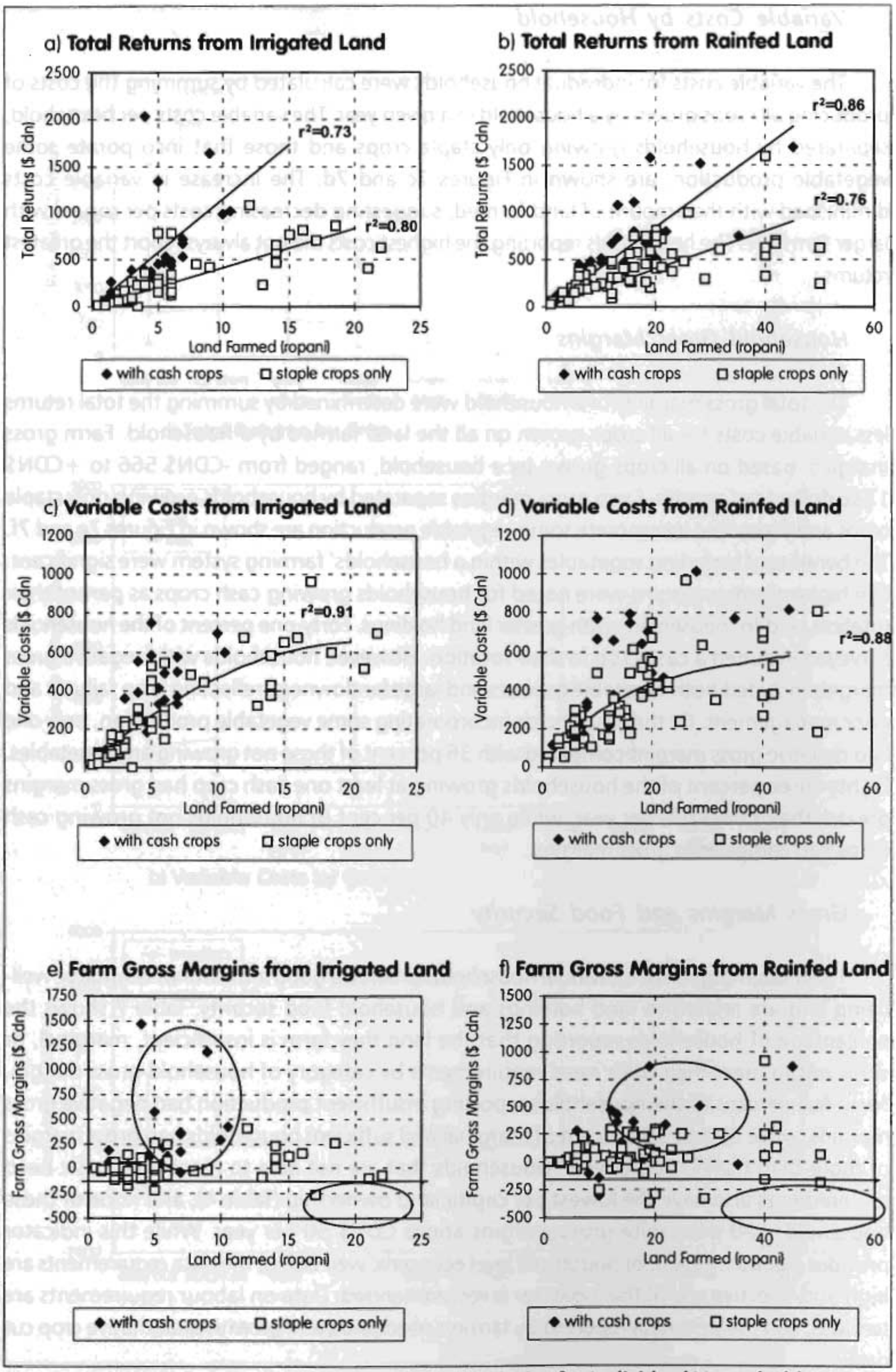

Figure 7: **Total Returns, Varible Costs and Gross Margins for Individual Households**

Table 7: **Self-sufficiency from Land Farmed Versus Household Gross Margins**

Sufficient	n	Household Gross Margins (% households)			
		< CDN$ 0	CND $ 0-100	> CND$ 100	> CND$ 50 per capita
No	11	45	55	27	0
Marginal	29	17	83	55	28
Yes	45	31	69	56	22

Conclusions

The economic well-being of households in the study area is strongly tied to the quantity and quality of land owned, and reflects traditional versus market-oriented agriculture (vegetable and milk production). Population growth averaging 2.6 per cent per annum from 1990-1995 has resulted in a reduction in the per capita availability of land. Land holdings were highly skewed between households and provided a good indicator of economic disparity between households. Ethnicity and the caste hierarchy are often related to access to land and capital resources, but are not a surrogate for economic well-being. The Chhetri households sampled owned no irrigated land and one household was landless. Livestock are an important component of the farming systems, both in relation to organic matter management and off-farm income (Shrestha 1999). Agricultural assets (land and livestock) were also highly skewed ranging from CDN$0 to CDN$ 53,000 per household. Household gross margins provide a mechanism for assessing the relative profitability of agricultural production between farms, and highlight the importance of cash crop production within the farming system. Households that included a cash crop within their rotation typically had higher gross margins than households growing only staple crops. Gross margins were related to land ownership and household food security, and provide a good indicator of household economic well-being. However, the data requirements vary between indicators. No single socioeconomic indicator encompasses the complexity of relationships within household farming systems, but a series of indicators are useful to indicate trends and relationships.

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Gender and Resources: Indicators and Interactions

Sandra Brown
Institute for Resources and Environment, University of British Columbia
Vancouver, Canada

Abstract

Gender issues are an integral component of the socioeconomic factors influencing the use and management of resources in the middle mountains of Nepal. In the Yarsha Khola watershed, women typically worked 13.5 hours per day compared to 9.7 for men. Women were largely responsible for domestic activities and livestock care, while decision making and farm management were controlled by men. Ninety-two percent of the adult women surveyed were illiterate, compared to 30 per cent of the adult men. Off-farm income increased with the education level of adult men, but women in these households had less decision-making powers. The Lamo Sangu Jiri road (constructed in the 1980s) has had an important impact in the watershed. Households with road access use more fertiliser and earn more from off-farm income, but women are left with greater responsibility. Households with poor access are more reliant on subsistence agriculture to meet their basic need requirements. On south-facing slopes near the road, lack of irrigation was identified by both men and women as the key constraint facing farm families, while across the watershed the unavailability of fertilisers was the primary concern. Issues raised by both men and women were similar, but women also identified labour shortages as a concern. Understanding the gender based division of labour, decision-making power, and access to and control over resources is key to implementing resource management programmes that will improve the situation for rural Nepalese women.

Introduction

Despite an emphasis on 'Women in Development' and 'Gender and Development' initiatives, little data exists on the situation of mountain women in Nepal and few analyses have been made of gender relations. Women in the middle mountains of Nepal are largely responsible for the day-to-day tasks within the farming system such as fetching water, domestic activities, livestock care, fodder collection, and gathering fuelwood. As the major suppliers of basic food, water, and fuelwood resources, women are affected most by environmental degradation. Resource degradation affects how women allocate their time, and consequently affects households and communities in many regions. Numerous papers and discussions have focused on resource degradation in Nepal, but without knowledge of how changes affect the workload of rural women it is difficult to suggest management options that will improve the situation.

The main objectives of the research described here were to:

- identify women's perspectives of key issues in natural resource degradation within a watershed context;
- define the gender-specific division of tasks within the farming system;
- identify recent changes in the workload of women, specifically those related to the collection of forest products;
- relate indicators of socioeconomic well-being to the workload of women; and,
- identify and initiate community-based programmes to reduce the impact of resource degradation on women.

Sampling Design

Resource use was evaluated at 337 sites within the Yarsha Khola watershed, Nepal. Management of irrigated and rainfed agriculture, and forest and rangeland were assessed through key informant interviews (Schonhuth and Kievelitz 1994) which included both men and women informants at all sites. The perspective of women farmers and forest user group members was targeted in order to understand better the issues faced by village women. Seventy-five detailed household surveys were conducted with female and male household heads and the results used to compile socioeconomic indicators that were then related to labour allocation and the workload of women. Simultaneous but separate male and female interviews were conducted to streamline data collection, provide a cross-check system, and to solicit open responses from women farmers. All sites were located on 1:5,000 and 1:20,000 scale aerial photographs to facilitate spatial analysis using geographic information system (GIS) techniques. Women's user groups in the watershed were identified and their input was used to develop community-based initiatives on topics of immediate concern to local women.

Indicators were used to identify poverty and gender inequity including labour, education, land holdings, off-farm employment, and agricultural production. Indicator interactions were then examined, and potential initiatives to overcome the 'gender gap' were documented.

The components of poverty and gender discussed in this paper are:

- a day in the life;
- labour allocation;
- socioeconomics; and
- agricultural constraints.

A Day in the Life

Time allocation was evaluated using daily diaries compiled for men and women farmers (Buenavista and Flora 1994). Daily diaries were completed during the first week of November (winter activities). The sampling design followed the resource use survey (Schreier *et al.* this volume): three elevation classes, two aspect classes, the central ridge, and three main ethnic groups (Brahmin, Chhetri, and Tamang). The activities of seven women and seven men farmers were documented for each combination of factors giving a total of 364 diaries.

A typical rural work day in the middle mountains of Nepal starts between 5:00 and 6:00 AM and involves the collection of water, fodder, and fuelwood; household tasks; crop production or off-farm employment (largely as labourers); cooking and cleaning; and bed between 8:30 and 9:30 PM. Women get up earlier, work longer, and spend a greater proportion of their day working (Table 8). Adult women typically work 3.8 hours per day longer than men.

Table 8: **Gender disparity in daily activities**

Activity	Women	Men
Wake up	4:57	5:39
Go to bed	21:19	20:41
Work (hrs/day)	13.5 hrs	9.7 hrs
% day working	82%	63%

Both men and women are active in crop production activities during harvesting and field preparation. In early November women were involved in harvesting millet grain, cutting millet straw, and manually digging fields in preparation for planting wheat. Men cut millet straw and ploughed fields for wheat. Even during this period when men were active in tasks related to crop production, women worked similar hours to men in the field in addition to their household-related activities.

Women living near the road spent significantly more time on household tasks and livestock care, worked longer days, and spent a greater proportion of their day working than women living on the non-road access side of the watershed. The longer work hours of women living near the road is likely to be related to the greater employment of men in this area, shifting the on-farm responsibility to the women.

Labour Allocation

Labour allocation was evaluated through a checklist approach in which women farmers identified who was responsible for a variety of tasks within the farming system (Feldstein and Poats 1994). Involvement was ranked on a scale of dominantly (90-100%), mostly (approximately 75%), 50-50, or some (approximately 25%).

Domestic activities (cleaning, cooking, childcare, fetching water) were largely the responsibility of women, as were tasks related to livestock care (Figure 8). Crop production typically involved shared responsibility, with women more involved in planting, gathering manure, and applying compost, and men in ploughing, terrace repair, and irrigation system maintenance. Farm management was dominated by men in over 60 per cent of households.

Access and ethnicity were two factors that influenced labour allocation. Households with road access (south facing aspect) displayed greater shared responsibility in the allocation of tasks between men and women. No significant differences were found between Brahmin

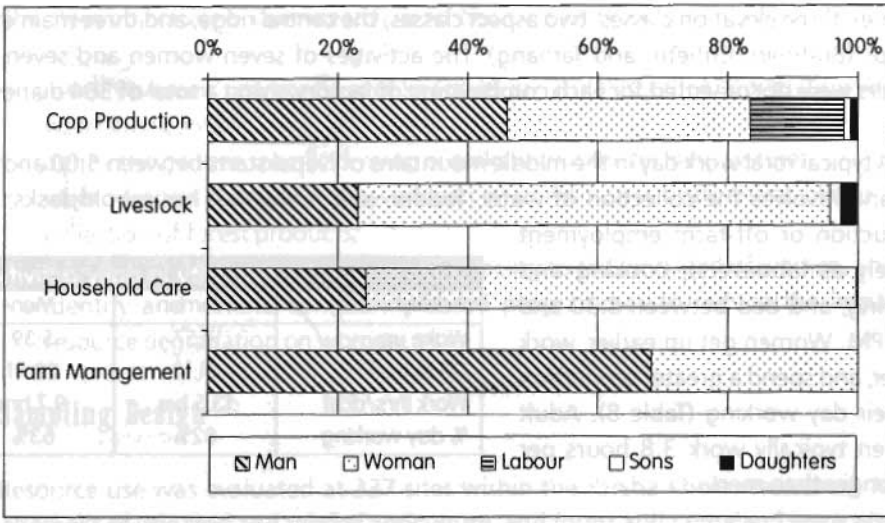

Figure 8: **Labour Allocation by Major Categories**

households and other ethnic groups, but males in Chhetri households appeared to take on more responsibility than Tamang men.

Socioeconomic Indicators

A range of socioeconomic indicators were evaluated including education, land holdings, basic needs, agricultural products sold, and off-farm employment. The male and female decision makers within each household were interviewed (n=150).

Ninety-two per cent of the adult females surveyed were illiterate, compared to 30 per cent of the adult males. A typical adult male had completed three years of school; a typical adult female zero years. While government programmes strive to reduce the gender disparity in education, girls in the surveyed families completed four years less formal education on average than their brothers.

The median land holding was 0.8 ha per household, but holdings were unevenly distributed with 67 per cent of the households owning only 38 per cent of the privately owned land, and having holdings of <1 ha (Figure 9). Fifty-three percent of the surveyed households were not able to fulfil their basic needs from the land they farmed. Households near the road were generally more reliant on off-farm income, while households on north facing sites (poor access) were more self-reliant (Figure 10).

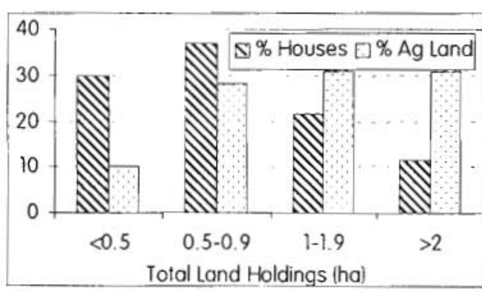

Figure 9: **Disparity in Land Ownership**

The main sources of cash income to farm families were the sale of agricultural products

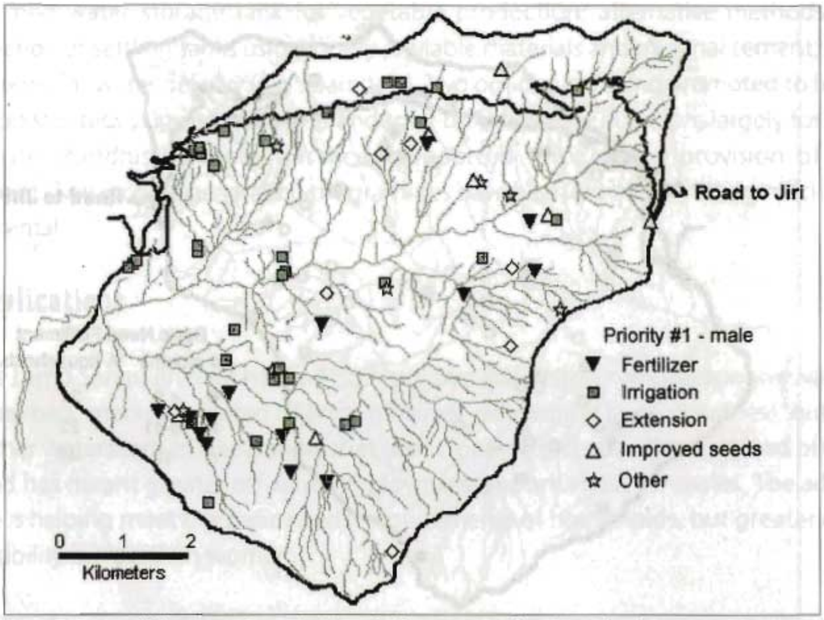

Figure 10: **Fulfilment of Basic Needs from Farming (symbols represent locations of farm households)**

and off-farm employment. Farmers sold a range of agricultural products, largely for local markets, but seed potatoes dominated both in amount sold and income earned. The average household earned CDN $81 per year from the sale of agricultural goods. Sixty-two percent of male household heads worked off-farm, the majority as seasonal labourers. The households with males working full-time were concentrated near the road. The average off-farm income was CDN $169 per year. Meeting household needs was seen overwhelmingly by female farmers as the biggest advantage of off-farm employment .

Agricultural Constraints

Both male and female household heads identified lack of irrigation and non-availability of fertiliser as the main constraints faced by farming households. Men identified lack of extension (information and education) on high yielding varieties, fertiliser costs, and pesticide availability as additional concerns, and women crop damage by insects and a shortage of labour. While the top two issues, irrigation and fertilisers, were identified by both women and men farmers the spatial distribution varied (Figure 11). Availability of fertiliser was identified as a major constraint on north facing slopes where access was limited (no road access); lack of irrigation was the key issue on south facing slopes that had road access but were hotter and drier than the north facing sites.

Interactions

The indicators of economic well-being, access, ethnicity, and labour allocation were inter-related. Poverty indicators (e.g., land ownership and total returns from agricultural

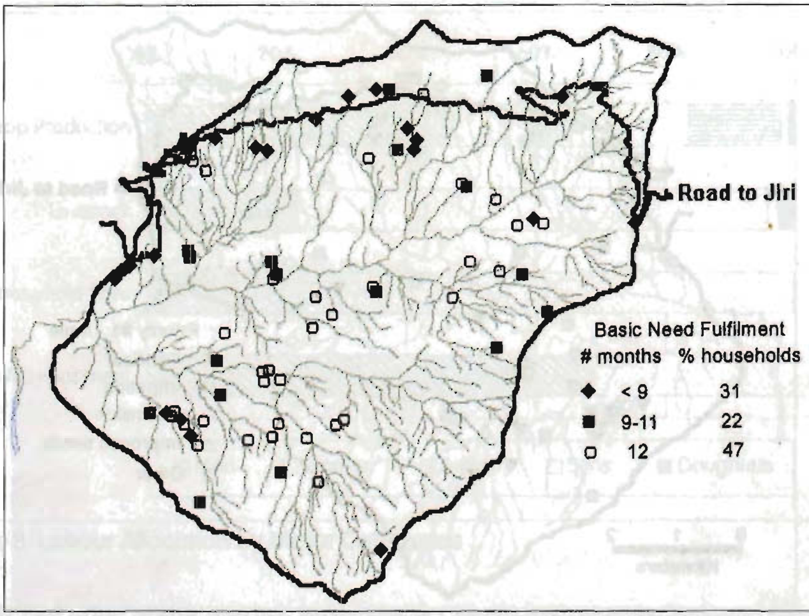

Figure 11: **Factors Influencing Constraints in Agriculture**

production) appeared to influence male education, that is the more affluent were better educated. Off-farm income increased with the education level of adult males but, interestingly, women in households with better educated males were less involved in decision making.

Land ownership was a key indicator of economic well-being. Households with greater land holdings produced more rice, maize, and millet, earned more from the sale of agricultural products, owned more livestock, and were better able to meet their families' basic need requirements.

The Lamo Sangu Jiri road has had a major impact on the Yarsha Khola watershed. Households with road access used more fertiliser and earned more from off-farm income. Households without road access were more reliant on subsistence agricultural production.

Initiatives to Reduce Gender Inequality and Poverty

A number of community-based projects focusing on resource management concerns in the watershed were developed in conjunction with local women's user groups (WUG). Groups were approached regarding their existing programmes and future goals. Community programmes were initiated related to a) irrigation, b) fuel efficiency, and c) education, based on scientific knowledge of the resource situation and opportunities identified by the WUGs.

Four water-related programmes are being investigated: a demonstration site on water harvesting for irrigation on a south facing aspect where water shortages are prevalent; a plastic-lined water storage tank for vegetable production; alternative methods for the construction of settling tanks using locally available materials and minimal cement; and low cost options for water delivery (e.g., bamboo). Two options are being promoted to help with fuelwood shortages: improved stoves and solar box cookers. Education, largely for Tamang (low caste, Buddhist) people, has been supported through the provision of science equipment. Two income generating programmes have been initiated: knitting machines and utensil rental.

Implications

The Lamo Sangu Jiri road has had both positive and negative impacts on the watershed. With the road, market-oriented opportunities are developing (e.g., potatoes), but studies from other watersheds in Nepal show that cash cropping increases the workload of women. The road has meant greater off-farm employment opportunities for males. The additional income is helping meet the basic needs' requirements of households, but greater on-farm responsibility is placed on women.

Male education and affluence did not appear to influence the status of women in the watershed. Knowledge is power—and educating women is critical to their involvement in community programmes. Illiterate women are not able to make informed decisions about the agreements they are asked to sign (e.g., in community forestry).

Women typically worked 3.8 hours more per day than men, with household activities (including the collection of water) averaging five hours per day. Resource degradation will mean more time spent collecting animal fodder, fuelwood, and water, increasing the already arduous workload of these rural Nepali women.

To promote women and their concerns within the watershed, this project initiated community-based programmes on issues raised by women and incorporating the concerns of low caste groups. Programmes related to water availability, fuelwood shortages, animal fodder shortages, education, and income generation are being developed. Programmes to reduce the workload of women include: a) the introduction of fuelwood efficient stoves, which reduce the amount of fuelwood collection required; b) fodder grass and tree seed distribution for on-farm planting to reduce the time spent by women collecting fodder; and c) community water distribution, reducing the time women spend collecting water.

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The Pivotal Role of Women in the Hills: Gender Analysis in Arah Village in Uttar Pradesh, Central Himalayas, India

Bhupendra S. Bisht, Sanjeev K. Bhuchar, Pushpa Pant, Bhagwati P. Kothyari and Lok Man S. Palni
GB Pant Institute of Himalayan Environment and Development,
Kosi-Katarmal, Almora (UP) 263 643, India

Abstract

Women of the rural central Himalayas play a pivotal role in sustaining the mountain economy and in upholding ecological and cultural values. Several studies suggest that women have varied and demanding occupations but the suggestions have rarely been supported by any data on energy expenditure. In the study described here, an attempt was made to analyse the major functional activities of women living in the remote central Himalayan village of Arah in the Kumaun hills in terms of energy expenditure (Mcal[1]per person per year). Women of four age classes, viz., 5-15, 16-35, 36-55, and above 55 years were analysed in terms of the energy used to perform various categories of work. The tasks analysed were performed exclusively by women, with the exception of a few activities in agriculture and animal care to which men also contributed. The maximum energy (average of the four classes for the individual category of work) was expended by women on household activities (169 Mcal per person per year), followed by agricultural operations (148 Mcal per person per year) and animal care (112 Mcal per person per year). The energy spent on different functions was also calculated for each age class. Girls in the age range 5-15 and women of 56 years and above spent their maximum energy on household activities (227 Mcal per person per year and 258 Mcal per person per year respectively), while women in the age ranges 16-35 and 36-55 expended the maximum energy on agricultural operations (313 Mcal and 246 Mcal per person per year respectively). Overall women in the age range 16 to 35 expended the most energy on average and those of 15 and under the least.

Introduction

Contemporary social studies largely focus on gender issues in energy and environment management. While the role of women varies in different parts of the world with the ecological, topographical, social, and cultural setting, their contribution towards preserving and sustaining ecological and socio-cultural values is widely recognised. In the rural areas of the central Himalayas in Uttar Pradesh, India, women of all ages play pivotal roles, and have varied and demanding chores to perform. The major duties undertaken by rural central Himalayan women are directly associated with access to common property resources and the quality of the natural resources (Gurung 1995). In this context, women in the mid-hills of the central Himalayas are subjected to a variety of stresses. The diminishing of natural resources and shrinking biodiversity of ecosystems have become matters of concern for society as a whole. One of the results is that there is an increasing tendency towards out-

1 1Mcal = 1 megacalorie = 1000 kcal; 1 calorie ~ 4.19 Joule

migration, particularly of men. Migration has served to undermine methods of natural resource management and has diverted communities away from investing energy and effort in their immediate environment (Myers *et al.* 1995). Long-term migration is steadily increasing, and this is increasing the workload of women (Bisht and Tiwari 1996; Rawat *et al.* 1997).

The functional value of women is very high as they share major responsibilities and perform a wide spectrum of duties in and outdoors. The role of women in terms of energy input to the rural ecosystem is more important than that of their male counterparts. They contribute more calories in performing necessary agricultural operations, household activities, chores related to animal care, and various routine jobs. In the rural Himalayas, practically all domestic and non-mechanised work is performed by women. Female participation in labour is also high (Vashudevan and Santosh 1987; Singh and Rawat 1992; Kadekodi 1997). The energy costs of common tasks in rural Nepal are summarised in Panter-Brick (1992).

The multiplicity of work performed and energy input by women is characterised by extensive interrelationships between such factors as the location of a village, social structure, age, composition of the family, environmental endowments, size of household, per capita land holding size, level of land fragmentation, irrigation conditions, cattle population and type of energy and resource base (Briscoe 1979; Bajracharya 1983; Vidyarthi 1984; Dewees 1989; Singh and Rawat 1992, 1993; Rawat and Kothyari 1994).

The hardships that women face result from the gender-based division of labour, their double work burden, the unequal distribution of resources that results from their subordinate status, and their lack of control over productive resources (including land) and cash. Against this backdrop, the lives of women are greatly affected, in ways different to men, by the environmental degradation that is occurring in the Himalayas as well as in other regions of the world (Venkateswaran 1992).

Detailed studies have been made on the lifestyles of women in Nepal (Acharya and Bennet 1981) and Garhwal (Reynolds and Nautiyal 1990). Both these and the present study in Kumaun show that the general condition of rural Himalayan woman is similar over a wide area in terms of the nature of work that is being performed. So far, however, there have been few studies on energy expenditure and none similar to the present one. A series of studies by Panter-Brick (1992, 1993, 1996) on women from rural Nepal largely focuses on issues such as nutritional efficiency, pregnancy and lactation, seasonality, and human biology but not on the parameters chosen here.

The study described in the following was concerned with the quantification of labour input in terms of the energy expended by rural women in performing major duties in a typical mid-mountain village in the central Himalayas. The valuable inputs made by men to complete certain activities like agriculture and animal care were also taken into account, but they were not analysed in terms of energy because the inputs were not comparable to the inputs by women.

The Study Site

The study site (Arah village) was located between 29° 59' 30" and 29° 59' 56" N and 79° 35' 20" and 79° 36' 15" E at an elevation of 1468 masl in Bageshwar district of Kumaun region in Uttar Pradesh in the central Himalayas. Arah is situated approximately 4 km from Garur Rural Service Centre (the road head), is spread over an area of 98.75 ha, and has limited essential amenities. Although the village is dependent on Garur town for both basic and essential amenities, it has a very strong social institution for dealing with problems related to the village community and resource management. In the early 1990s the village population was 543 (288 male and 255 female), the livestock population was 326, and cultivated land totalled 52 ha (rainfed and irrigated). The agricultural areas are surrounded by pine forest.

Methodology

Detailed investigations of the actual workload of Arah women and their equivalent energy inputs into various tasks were carried out during 1993-96. A complete inventory was made of work performed in the major areas of household activities, animal care and related activities, and agricultural operations using a questionnaire prepared for the purpose.

Forty of the 86 households in the village were selected for detailed study. Family size, landholding size and type of agriculture (rainfed and irrigated), livestock number and type, and other factors were taken into account in the selection of households. After a preliminary survey, the women were grouped into four age classes (5-15, 16-35, 36-55, and >55 years) to reflect their physical capabilities, socioeconomic position, the nature of work they usually perform, and the inherited traditional family responsibilities. Ten women per age group were sampled with random selection for each class.

The activities were evaluated in terms of the total number of hours per person per age class per year for performing each operation. The energy equivalents for performing sedentary (79 kcal per hr), moderate (117 kcal per hr), and heavy work (217 kcal per hr) were calculated using the methods given in Gopalan *et al.* (1985). Gopalan *et al.* give eight hours per day as the average that women perform moderate and hard work, a value supported by our total study samples.

Study Groups

Group I (5-15 years)

Traditionally in the rural central Himalayas women are forced to take on responsibilities from childhood. Rural girls normally start providing a contribution to household and related activities from the age of 5-6 years; at the age of 9-10 years they are considered 'fully trained' and able to act as independent units in the female work force. In the modern setting of rural society, education has also been introduced as an essential part of their lives. Almost every day, before and after attending school, they perform many tasks related to the household and other sectors.

Group II (16-35 Years)

Rural women in this age group are considered fully mature and able to take complete independent household responsibility for a family. This age group is physically strong and is used to the maximum limit in terms of energy input in all sectors, including family affairs and social responsibilities. However, they are not supposed to take independent 'decisions' on any matters outside routine household duties. The average age of marriage for women in the Arah area is 17 years.

Group III (36-55 years)

Rural women of this age feel slightly relieved and try to join the older groups. They are allowed to take 'decisions' on agriculture and related activities and to take an active part in social activities. They work in agriculture, animal care, and household activities. Once they reach the age of 50-54 years, a new generation (work force) is usually ready to take up most of the responsibilities outside normal household activities.

Group IV (above 55 years)

Women of this age group are physically weaker but remain 'in charge' of household activities and are very particular about the regulation of family affairs, a responsibility which is traditionally inherited. They keep themselves busy with household, animal care, and social activities.

Results and Discussion

The study showed that there was a clear division of labour between the women in different age groups (Table 9).

On average, the most energy overall was expended on household activities (170 Mcal per woman per year) followed by agricultural activities and work related to animal care. The

Table 9: **Average Energy Inputs by Women in Different Age Groups for Different Types of Tasks (Mcal per person per year)**

Activities	Energy Input				
	5-15 yrs (I)	16-35 yrs (II)	36-55 yrs (III)	>55 yrs (IV)	Average
Household	226.6	111.4	81.7	257.9	169.4
Animal care	103.6	79.9	127.1	138.1	112.2
Agriculture	14.2	313.4	246.1	20.0	148.4
Total	344.4	504.6	454.9	416.1	430.0

greatest amount of energy overall was expended by the women aged 16 to 35 (505 Mcal per person per year) and the least by the youngest group (344 Mcal per person per year). There was no direct correlation between age and energy input, but there was a clear-cut demarcation of specific work and responsibilities for women of different age groups.

Household Activities

Household activities include fetching water, cooking, childcare, and collecting firewood; education (attending school) was also included in this category. All these chores require major and regular energy inputs. The majority of household activities fall under the sedentary or moderate category of work. Table 10 shows the average energy inputs per year for different household tasks according to age group and overall.

The oldest age group contributed the most energy to household work (258 Mcal per person per year), mostly in the form of cooking and childcare, and the group aged 36 to 55 years the least (82 Mcal per person per year). The large contribution by the youngest group resulted from the inclusion of education in household activities. If this is discounted then their overall contribution is only a little more than that of the group aged 36 to 55 years. Overall most energy was spent on cooking and associated activities (56 Mcal per person per year), and the least on collecting firewood (1.4 Mcal per person per year).

In this village collection of water does not require as much energy as in many places because drinking water is available in the village from community water posts, private water connections, or a *naula* (spring). The youngest age group contributed the most energy to water collection.

The oldest age group made by far the largest contribution to cooking and related activities (116 Mcal per person per year), with similar, but much smaller, contributions by all the other groups. Essentially, the oldest age group did the actual cooking and other groups available indoors performed associated activities. Men also helped to prepare midday meals during the peak agricultural seasons.

The study village is surrounded by a good pine forest so firewood collection was not a major problem, and this activity was a low energy input sector for the village women. The

Table 10: **Average Energy Inputs for Household Activities by Women in Different Age Groups (Mcal per person per year)**

Activities	Energy Input				
	5-15 yrs (I)	16-35 yrs (II)	36-55 yrs (III)	>55 yrs (IV)	Average
Water collection	55.6	44.8	30.7	38.3	42.3
Cooking	36.0	29.0	42.7	115.6	55.8
Firewood collection	0.6	2.6	2.6	0	1.4
Education	134.4	9.1	0	0	35.9
Child care	0	26.0	5.7	104.0	33.9
Total	226.6	111.4	81.7	257.9	169.4

middle age groups contributed the most of this small amount. Occasionally men also assisted in felling and cutting of logs used for firewood.

One of the most important activities in the household sector is childcare. The oldest age group contributed the most energy for this (104 Mcal per person per year), followed by a much smaller contribution from the 16 to 35 year old group (Group II, 26 Mcal per person per year). The Group II women were mostly responsible for childbirth and the care of babies, but women in the oldest group took most of the responsibility for childcare activities overall as the women in Group II were busy in other sectors like agriculture and animal care. It is not uncommon for this lack of time and burden of work on the part of mothers to lead to poor health of both mother and child and even contribute to premature death. Surprisingly the youngest group played no part in activities related to childcare.

Only unmarried girls went to school, i.e., those in Group I and a few girls over 16. For secondary and higher-secondary education students have to walk to Garur town (approximately 4 km from the village). A major part of the energy input in this sector was due to daily return journeys between village and school.

Animal Care Activities

Animal husbandry is an important sector in the rural central Himalayas. The major tasks are care of cattle (and buffalo) during open grazing, care of cattle (and buffalo) at the homestead, and collection of fodder and leaf litter (for bedding). The average number of livestock per family was four (mid 1990s). The large livestock in Arah village comprised cattle (53% of all animals), buffalo (36.2%), goats (9.4%), sheep (0.7%), and horses (0.7%).

Table 11 shows the average energy inputs by women per year for different tasks associated with animal care according to age group and overall. On average every woman contributed 112 Mcal per year to these activities. The maximum energy input was used for the care of stall-fed cattle and the collection of fodder (36 Mcal per person per year for each activity), closely followed by care of cattle during open grazing. Considerably less energy was expended in leaf litter collection.

Table 11: **Average Energy Inputs for Animal Care by Women in Different Age Groups (Mcal per person per year)**

Activities	Energy Input				
	5-15 yrs (I)	16-35 yrs (II)	36-55 yrs (III)	>55 yrs (IV)	Average
Care of cattle during open grazing	49.0	7.1	11.5	51.1	29.7
Care of stall-fed cattle	19.6	24.4	36.7	63.9	36.2
Collection of fodder	21.3	38.5	63.7	21.0	36.1
Collection of leaf litter	13.7	09.9	15.2	2.2	10.2
Total	103.6	79.9	127.1	138.1	112.2

The oldest women contributed the most energy overall per person to animal care (138 Mcal per year) and the 16 to 35 year-old group the least (80 Mcal per person per year), although all groups contributed significantly.

The share of energy contributed by women in different age groups varied according to the task. Cattle care during open grazing was mainly performed by the oldest and youngest women and girls. This work is considered sedentary and thus suitable for physically weaker women. Older and physically weaker men sometimes take on this task. In contrast, the energy input for the care of stall fed cattle was directly correlated with age, with the youngest contributing the least and the oldest the most.

Fodder collection is a major activity and includes collection of agricultural residues, collection of green fodder (for daily use), and harvesting of dry grass during the autumn to be stored for the winter months. Fodder collection is a supplementary activity when animals graze outside, but compulsory for stall fed animals. Generally families need to collect 40-60 kg per day, and in almost all cases women are responsible (Reynolds and Nautiyal 1990). Some fodder is obtained from the agricultural harvest and some from on-farm trees grown on the terrace margins. However, for much of the year women must make daily journeys to collect leafy branches and grass from the forest. In badly deforested regions, and especially in centrally situated villages, women of all ages might walk 10-20 km and back to find fodder and carry head-loads weighing from 20-40 kg (Nautiyal 1982; Nautiyal and Nautiyal 1983). Green fodder (grass and leaf fodder) is considered a luxury for cattle during winter in this region and is fed preferentially to milk giving animals. *Grewia oppositifolia* is considered the best green fodder in winter but is generally available in small quantities only. Except for the collection of green grass and leaf fodder from nearby agricultural fields, fodder collection was mostly done by the women of medium age (groups II and III).

Collection of 'leaf litter' from nearby forests for animal bedding is a very common activity. Although pine needles are not considered good for composted manure, they are the only material available in sufficient quantity near many villages in the Arah area. Collection of pine needles is a seasonal activity and is carried out during May and June. Traditionally pine needles are also used for burning on selected agricultural fields, for example while preparing paddy nurseries. This is because of the commonly held belief that fire helps to eradicate weeds—concomitant damage to soil micro-organisms and earthworms is not considered. The energy input into this activity was mostly divided between the women in the three younger groups, women in the oldest group contributed little.

Agricultural Activities

According to Swarup (1991), hill agriculture is very complex but universally highly dependent on women's labour. It is based on traditional methods, which are labour intensive with low external inputs. Rural women are busy round the year with agricultural operations, but the average total yield is generally low and the crop only sufficient to feed the family for five to six months.

In Arah village, the agriculture system can be classified into two types: rainfed (about 90%) and irrigated (about 10%). Agricultural operations broadly include activities like field preparation and sowing/transplantation, and operations related to yield enhancement, protection, harvesting, and storage.

Table 12 shows the average energy inputs by women per year for different tasks associated with agriculture according to age group and overall. On average every woman contributed 148 Mcal per year to these activities, but the vast majority of the activities were performed by women in the two middle age groups from 16 to 55 years who contributed 313 and 246 Mcal per person per year. The youngest and oldest contributed little energy. The maximum energy input was into yield increasing activities and the least in field preparation.

Field preparation, which is the first step, consists of such activities as breaking up clods of soil, digging the terrace margins (where planting is not possible), sowing, and transplantation (during *Kharif*; May to July). This is one of the sectors where traditionally the men contribute energy for ploughing, and for watering before or after ploughing. Bullocks, an essential part of the cattle population, are used during field preparation and for some other agricultural operations during the year. Women of 36 to 55 years contributed the most energy to this task (36 Mcal per person per year), slightly more than those of 16 to 35 years. The oldest women contributed the least.

Yield increasing activities basically cover collection, transport, and incorporation of fertiliser, mostly composted manure, and were considered the most tedious and tiresome of all the agricultural activities. Addition of composted manure was the main measure for improving soil fertility. The manure was added preferentially to irrigated fields as rainfed agriculture was considered uneconomic (three crops in two years). Only a small amount of manure was spread on the rainfed fields. Almost all the households had some irrigated agricultural lands along the Garur Ganga or Gomti river (Garur valley), approximately four kilometres below the village. The manure had to be transported by head-load from the cattle sheds in the village to the distant fields. Although inorganic fertilisers were also used in limited amounts, this had no direct effect on the quantity of manure transported and applied to the fields. The major part of the total energy input into this sector was expended in transportation. Women in the 16 to 35 years age group contributed the most energy to this activity (167 Mcal per person per year) followed by those of 36 to 55 years.

Table 12: **Average Energy Inputs into Agricultural Activities by Women in Different Age Groups (Mcal per person per year)**

Activities	Energy Input				
	5-15 yrs (I)	16-35 yrs (II)	36-55 yrs (III)	>55 yrs (IV)	Average
Field preparation	5.2	29.5	36.3	2.3	18.3
Yield increase	3.6	167.2	92.5	0	65.8
Yield protection	0.1	53.3	31.7	5.5	22.7
Yield collection	5.3	63.4	85.6	12.2	41.6
Total	14.2	313.4	246.1	20.0	148.4

Yield protection activities include weeding, breaking up the soil surface, and protection from wild animals and diseases. Although the actual activities related to yield protection are considered sedentary, substantial time and strength is required to cover the long distances between the village and the fields. Crop protection is directly related to the return on investment, so the job is considered important and not suitable for children. Equally the most experienced women are physically weaker and not able to cover the long distances frequently. Thus women of 16 to 35 years contributed the most energy to this task followed by those of 36 to 55 years, with only a small contribution by the oldest and virtually none by the youngest.

In the rural setting of Arah village, yield collection is the last event in the agricultural cycle. The major activities are harvesting, transportation, threshing, drying, and storage. Harvesting of crops and transportation to the village are hard tasks usually done by women in the middle age groups. Threshing is a mixed effort done collectively by men and women and by using bullocks. Women in the older age groups (over 36) usually perform drying and storage activities with occasional assistance from anyone around, including men. Overall women of 36 to 55 contributed the most energy followed by those of 16 to 35 years with lesser contributions from the oldest and youngest.

Conclusions and Recommendations

Women constitute the backbone of the Himalayan economic system and contribute substantially to the economic growth of the region (Bhandari 1991; Samal 1993). They have major responsibilities in the fields of agriculture, cattle, and collection of fuel, fodder, and water, in addition to a plethora of duties at home. These oft-quoted general statements are substantiated by the present findings. The women in the study village expended large amounts of energy in all sectors of life. It is clear that development programmes for such villages need to take a serious note of the division of labour within households, and adopt a thoughtful, researched, holistic approach when considering the individuals who will carry out initiatives and development activities.

Some of the conclusions reached by the research team in Arah village are summarised below.

- The rehabilitation of degraded land in and around villages of the mid-hills, which accounts for up to 50 per cent of land in some areas, will only be relevant and sustainable if emphasis is given to the role that the women play in community resource management. The production of quality fodder and firewood and plantation of easily managed cash crops both on-farm and on degraded lands will have a direct beneficial effect on the workload of women.
- Selection of tree and grass species for rehabilitation of wastelands needs to be made on the basis of both socioeconomic impact and ecological values. The tree species recommended for mid altitude zones on the basis of villagers' practices and

ecological suitability are *Alnus, Bauhinia, Celtis, Dalbergia, Ficus, Grewia, Quercus, Dendrocalamus* and some perennial grasses.

- All natural resource management training activities (e.g., on the management of biomass production, water, animal husbandry, eco-technologies for horticulture and agriculture, planning and budgeting, and monitoring and evaluating) should focus on women. Women need to be apprised of the advantages of a judicious blend of ecological prudence with traditional technologies (Valdiya 1997).
- A reduction in the number of poor quality cattle and replacement with fewer economically more beneficial animals could substantially reduce the drudgery of women. Stall feeding of a few productive animals would reduce open grazing and improve the production of milk and of compost manure.
- Education on basic sanitation, health, and hygiene could improve the working capacity and living standards of hill women.
- Development of rural service centres must be associated with the development of road networks. Essential basic institutions like primary health and secondary education centres need to be provided in close proximity to the villages to facilitate the needy and to reduce travelling time.
- The increasing trend of rural out-migration by the male population has increased the workload on women. Development of rural service centres would reduce temporary migration. Encouragement in setting up small-scale industries, for example fruit processing units, could result in considerable benefits for employment and the economy.
- Across the Himalayan region, there need to be opportunities for women to train in specific tasks like mushroom cultivation, handicrafts, plantation, beekeeping and honey production, fruit preservation, cultivation of herbs, sewing, sericulture (silkworm breeding), and rabbit breeding. This should be done in such a way that the imparted skills reduce the overall workload of women and do not add to their existing chores.

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Gender Analysis in the Xizhuang Watershed: A Case Study from Wangjia Village

Zhu Xia
Yunnan Academy of Social Sciences, Kunming
Yunnan Province, China

Abstract

Women play an important role in the agricultural farming system in Xizhuang Watershed. The case study indicates that most men aged between 20 and 50 years spend about 6 to 10 months per year, and some many years, off-farm outside the watershed on income-generating activities to support their families. The men usually return for the busiest seasons in the agricultural year. This indicates that women are the custodians of most on-farm activities. Women are responsible for most domestic activities, livestock husbandry, childcare, and family education, but decision making and management are largely controlled by men. In 80 per cent of the households surveyed, women were the bankers and men the source of family income. However, traditionally the legal rights of women are not recognised, and women don't have the confidence and education to defend their rights. The majority of dropouts after primary school are girls as many traditional families believe that girls are not as intelligent as boys and not worth investing in, and most families believe that girls should take on extra responsibilities at home. Health and hygiene awareness among the rural population are poor; health facilities are limited and expensive. Poverty often results in poor nutrition and health. Education, legal rights, decision-making power, and control over resources is essential to improve the situation of rural women in the watershed.

Introduction

The People and Resource Dynamics Project (PARDYP) aims to have both direct and indirect impacts on biophysical and socioeconomic conditions, local resource management, and community and local government decision-making and planning processes in the watersheds studied, and to provide information that can be used to achieve these aims across the region. The Kunming Institute of Botany of the Chinese Academy of Sciences has been carrying out activities related to the objectives of PARDYP in the Xizhuang watershed. The watershed is located near Baoshan, it contains two administrative villages covering 10 natural villages, and has a population of 3900. The study described here was concerned with the identification and analysis of gender differences in practices related to resource management.

Study Objectives

It is crucial to the project to understand the socioeconomic dynamics in the project area, particularly gender related aspects of resource management such as gender variation in knowledge, practices, management systems, and decision-making. Ignorance of gender differences often leads to project failure.

The objectives of the study described here were:

- to understand the role of women in the agricultural farming system;
- to determine gender differences in land use and property rights;
- to analyse women's access to the education system from a historical perspective;
- to assess local health care services;
- to compare men and women's roles in decision making; and
- to provide recommendations for project implementation and local land use planning.

Methodology

Wangjia village was selected for the study. A total of 10 days were spent in the field. Interviews were conducted in 18 of the households in the village, primarily with women. The methods used included:

- participatory observation;
- key informant interviews—e.g., with an 84 year-old woman;
- semi-structured interviews (using checklists) with 17 women aged from 20 to 50 years in rich, moderately well-off, poor, and very poor families;
- group discussions with women and men.

Research Findings and Discussion

Wangjia Village

Wangjia village is 25 km from Baoshan City to which it is linked by a rough watershed road that is difficult to traverse, especially in the rainy season. Watershed residents often walk the two hours to the market in Banqiao. The village is located on a valley slope. A stream separates the village into two hamlets, Lydia village and Ganglia village. The village has a total of 96 households and a population of 414, of which 200 are female. All the village people are from the Han ethnic group. There are three main families, the 'Wan', 'Li', and 'Zhang' families. About half of the households and the village head belong to the 'Wan' family. A three-storey primary school was constructed recently near the village.

Land Use and Cash Income

Wangjia village has a total of 265 *mu* (17.7 ha) of arable land with an average of 0.8 *mu* (0.05 ha) per person. Two main crops are cultivated, wheat in spring and maize in autumn. In 1996, total production was 136 tonnes of maize and 53.5 tonnes of wheat—an average of about 500 kg grain per person per year. The staple food is maize, wheat, and rice. Only a few households can afford to eat rice every day, and the staple diet for most families consists of two-thirds maize and one-third rice. Poor families consume mainly maize and wheat with occasional rice during guests' visits and festivals. Women usually exchange their maize for rice (2 kg maize for 1 kg rice) through middlemen. Both rich and poor have three meals a day.

After paying the agricultural tax on grain, only 3 of the 17 households interviewed had surplus grain to sell in the market. The income from grain is very low.

Drinking water from the nearby spring is clean and unpolluted. Some villagers use bamboo pipes to deliver spring water to their houses. Other families spend five minutes per load to carry water from the water source.

Most houses are built from wood, tiles, and sun-dried mud brick. A few richer families buy bricks and cement to build their houses. The houses generally have two stories with a living area on the first floor and a grain store on the second floor. Grain is dried in front of the house. Animal stalls are on one side of the house, the kitchen on the other.

The cost of house construction is very high compared with local incomes. An ordinary house costs about RMB 15,000-20,000[1] to build. According to tradition, parents are expected to help their sons to build a house. If a family has many sons, building or dividing houses is a major household problem.

Most families use the energy-saving stoves recommended by the government. Over the year a woman spends about 40-60 working days, the majority during winter, in the collection of fuelwood, pine needles, and leaf litter. At present, one working day is worth about RMB 15. Leaf litter from the forests is used both for fuel and as compost material. Women put leaf litter into pigstys for bedding and subsequent production of compost. Some families sell fuelwood and pine needle ropes (for lighting) in the local markets for cash income; the average income from this source for those involved ranges from RMB 1,000-2,000 per household per year.

Women—The Backbone of the Farming System

Tea plantations and raising pigs are the most important sources of cash income. Tea gardens were introduced in 1982 after a shift from the people's commune to the household responsibility system. Some households have reclaimed wasteland to plant tea.

Women are usually responsible for the management of tea gardens and raising pigs. Women spend about two hours on pig raising every day—this includes the collection of green fodder from the forest. The income from raising pigs varies from family to family within the range RMB 500 to RMB 4,000 per annum. Most families do not have sufficient grain to feed the pigs enough to obtain maximum benefit. All families need at least one pig for the Spring Festival (New Year) and for the provision of salted meat all the year round.

In 1999, There were 8.28 RMB to one US$

Tea can be picked three times a year, spring, summer, and autumn. The season for spring tea lasts 30 to 40 days, for summer tea 15 to 20 days, and for fall tea 15 days. Women are always responsible for picking tea. They usually wake very early, leave for the tea garden after a simple breakfast, lunch in the field, and come back late. They spend 12-14 hours in the garden, picking between 20 and 40 kg of fresh tea per day. During the year, a woman spends 60-75 days picking tea. They either process the tea at home or sell fresh leaf to a small processing factory in Lijiashi village. The annual income from tea per household varies from RMB 500 to RMB 3,500, according to the quantity and quality of the tea. Other products like chickens, mushrooms, pine nuts, and fruit also provide some income.

Most men from Wangjia village work away from the watershed in urban areas, leaving the farming activities in the hands of their wives. Commonly, men between 20 and 50 years of age spend about 6 to 10 months on off-farm work outside the watershed. A few men work away from home for many years. During the busy farm seasons, usually twice a year, they return home for periods of between one and three months to help their wives to harvest and sow. When these busy seasons pass, they leave the village again to search for work elsewhere. Thus most farm work is undertaken by women. The cycle of activities, performance by men and/or women, and the marketable products over the year are shown in Table 13.

<u>An Example of A Household: Mrs. Wan Yulan's Family</u>

At the time of the interview the family had five members (2 men, 2 women, a 50 day-old baby). In 1997, the 26 year-old son worked for nine months on the state forest farm in logging and transportation. He earned between RMB 13 and RMB 15 per day. His father, mother, and wife lived together in the village and were responsible for the farm. The main farm income derived from selling tea (RMB 2,400) and two pigs (RMB 2100). The son returned home to help his family during the busy periods.

The major farming activities during the 1997 farming season are described in the Box.

The labour division in this family can be summarised as follows.

- Over the year, the son did only 16 days of actual farm work, and spent a small amount of additional time on minor farming activities and housework.
- The father did 52 days of on-farm work, and also cared for the two cattle.
- The son's wife did 110 days of farm work.
- The son's mother did 170 days of farm work.

Eight days labour were received in exchange from other families, and returned at another date. Exchanging labour days, particularly with relatives, is very common in rural areas in Yunnan.

As seen from the example, women contribute by far the largest amount of labour for direct farm work. They also spend a lot of time on other 'minor' work like taking care of the

Table 13: **The Agricultural Calendar**

Month	Farming activities	Labour intensity	Rainfall cm	Labour division	Marketable products
Jan	Collecting litter and fuelwood	+	Snow	Collecting litter (f) Collecting fuelwood (f,m) Off-farm job (m)	Pigs (f,m)
Feb	Collecting litter and fuelwood	+	Snow	Collecting litter (f) Collecting fuelwood (f,m) Off-farm job (m)	
Mar	Picking tea, raising maize seedlings	+ +	0	Picking tea (f) Raising maize seedlings (f, m)	Tea (f, m)
Apr	Picking tea, carrying manure, harvesting wheat	+ + + +	1	Picking tea (f) Carrying manure (m) Harvesting wheat (f) Carrying wheat (m)	Tea (f, m)
May	Picking tea, harvesting wheat, planting maize	+ + + + +	3	Picking tea (f) Harvesting wheat (f) Carrying wheat (m) Ploughing (m) Digging (m,f) Sowing (f)	Tea (f, m)
Jun	Picking tea, planting maize	+ + +	9	Picking tea (f) Digging (m, f) Sowing (f)	Tea (f, m), Peaches (f),
Jul	Tea picking, weeding, tilling maize field	+ +	10	Picking tea (f) Weeding and tilling (f, m) Off-farm (m)	Tea (f, m) Pigs (f, m) Mushroom s (f) Apples (f) Peaches (f)
Aug	Picking tea, weeding, tilling soil for maize	+ +	10	Picking tea (f) Weeding and tilling (f, m) Off-farm job (m)	Tea (f), Pigs (f, m)
Sep	Picking tea	+	5	Picking tea (f) Odd jobs (m)	Tea (f)
Oct	Harvesting maize, planting wheat	+ + +	4	Harvesting maize (f) Carrying maize (m) Ploughing (m) Digging (m, f) Sowing (f)	Pine nuts (f)
Nov	Collecting litter and fuelwood, applying manure, tilling the tea garden	+	0	Collecting litter (f) Collecting fuelwood (f,m) Applying manure and loosening the soil (f) Off-farm job (m)	Pine nuts (f) Fuelwood (f) Pine needles (f)
Dec	Shelling maize, collecting litter and fuelwood	+	0	Shelling maize (f) Collecting litter (f) Collecting fuelwood (f, m) Off-farm job (m)	Pine needles (f) Fuelwood (f)

Note: f—performed by women; m—performed by men

vegetable garden, collecting mushrooms and pine nuts, and harvesting fruit from orchards. Housework—laundry, cooking, childcare, cleaning house, mending clothes—is also the responsibility of women.

Box 1
FARMING ACTIVITIES

The major farming activities of Mrs. Wan Yulan's household in 1997

Farming activities performed by men and women

- Raising maize seedlings in plastic bags: wife and mother together, 6 working-days
- Harvesting wheat: son, wife, mother, and father together, 12 days; exchange labour, 4 days
- Planting maize: 4 labourers together, 20 days; exchanged labour, 3 days
- First weeding, loosening soil: wife, mother, and father together, 12 days
- Second weeding, loosening soil: wife, mother, and father together, 12 days
- Harvesting maize: son, wife, mother, and father together, 20 days; exchange labour, 1 day
- Planting wheat: son, wife, mother, and father together, 12 days
- Applying manure, loosening soil in tea plantation: wife, mother, and father together, first time 12 days, second time 12 days
- Collecting fuelwood: father and mother together, 30 days
- Spraying pesticide twice: father, 2 days

Farming activities performed by men only

- Ploughing maize fields: father, 2 days
- Ploughing wheat fields: father, 2 days

Farming activities performed by women only

- Picking tea: wife and mother together, 140 days
- Collecting forest litter: mother only (wife pregnant), 60 days
- Raising pigs: wife and mother, 2 hours per day
- Shelling maize: wife and mother, 5 evenings

The Range of Women's Work and the Importance of their Role is not Well Recognised by Men or by the Rural Society

Women's farm work takes much time and energy, but the work is generally considered to be easy and simple. In terms of difficulty and hard work, farm management tasks are considered to range from hard to easy in the following order: ploughing, managing horses and cattle, land preparation, collecting forest litter and fuelwood, plucking tea, weeding, and spraying pesticides. Men are often responsible for labour intensive work such as ploughing, but this generally only occurs twice a year for short periods. The tea picking done by women may be less labour intensive but it lasts for longer—more than 2 months. Some families hire women labourers for tea picking.

Before the 1980s, all farmers worked for the people's commune. Their income and grain supply were based on the accumulation of work-points they had earned in the past year. Work-points, recorded each night for each individual by an accountant, indicated the quantity and quality of labour performed. Different work earned a different number of work-points—heavy or difficult work earned more work-points, easier and simpler work earned less. At the same time, men and women earned a different number of work-points for the same task, 10 work-points for a strong male labourer compared to 8 for a strong female. Thus women's payments were always at least 20 per cent lower than those of men.

It is clear that women are the main on-farm workforce and the more productive sector. They are deeply involved in almost all aspects of agricultural activities and rural daily life, and contribute their entire life to the family and community. However, their contribution and the value of their work is consistently underestimated and neglected.

Land and House Property Rights: Are Men's and Women's Rights the Same?

In 1982, Wangjia village started to practice the economic reform policies dictated by the state. The collective lands were distributed to families according to a points system—adults scored 10 points, the old scored 6 points, and children scored 4 points. Good and bad land was shared evenly, and to achieve this families were often allocated four to eight dispersed small plots. These small dispersed plots are inefficient from the point of view of land management, but the villagers are generally satisfied with the distribution.

Following the land distribution, the families received a contract booklet. In Wangjia this was in the name of the male head of household, as men are considered to be the heads of families. In other areas both men and women, including unmarried daughters, obtained a share of land at the time of distribution. This clearly implies that women do have legal rights to the land. Indeed, the Chinese government has tried to award equal rights to women.

Since 1982, every family in Wangjia village has had a long-term land contract with the village administration. The household contract responsibility system permits the householders to use the land for a long time, but they have to pay agricultural taxes on grain according to the quantity of allocated land. The households have land to earn their living, but they still do not have rights of ownership of 'their' land. Unlike in other communities in Yunnan, the lands in Wangjia village have never been redistributed and the 'land ownership' is the same as in 1982.

What has happened in the fifteen years since the land was distributed? In rural areas, people still practise the traditional patrilineal, partriarchal family system. A woman has to leave the community in which she grew up when she marries and join her new husband in his village. Thus when daughters married and moved out, they lost their share of land in their own village. Women are not permitted to sell or use their land share and have to leave it to brothers or other members of their blood family. Even if they marry in the same village or nearby, they are still not permitted to use 'their' land. As a result, some of the families in Wangjia village that had more daughters at the time of land distribution experienced an increase in land when the daughters grew up and married. This land has generally been passed on to their brothers. The land has always been handed down to males.

Are the rights of the men and woman to the land the same? Legally, yes: actually, no. When girls are in their family of birth they are often treated as outsiders. If the son and daughter quarrel the mother often speaks to the son as follows: "Treat your sister well, she will not stay long here. She will soon be a member of another family. Be patient." Girls are taught not to try to share the property with their brothers. When asked if they wanted to inherit their parents' property, young female members of a family expressed shame and answered: "We never think about it." At marriage, women are officially registered as members of their husband's households, and after marriage the new couple splits from the wife's family, especially if the family has two or more sons. The property of families is divided at the time of marriage of a son rather than after the parents' death. The allocated properties belong to the husbands. Widows face special problems. On the death of her husband, a widow risks losing land and property to her brother-in-law if she has no son. She is generally not allowed to return to her family of birth because her own brother would resent her reappearance.

Family conflicts also pose problems. A Chinese proverb says "a married daughter is like water spilt outside". When a woman has a conflict with her husband or members of his family, her own family of birth can be a temporary refuge, but she cannot stay permanently. This situation might explain why the divorce rate is very low in this area. When the head of the womens' group was asked about divorce, she said that nobody had divorced in the three villages nearby and that it was a most unusual occurrence. After completion of the Wangjia village studies it was discovered that two women of the village had divorced and left their husbands, but the interviewees had been too ashamed to record this information during the survey. On leaving their husbands, these women took nothing with them and went to places as far away as they could; one is now in Jiangshu Province the other in Baoshan city. These two women are considered to have 'escaped'. Women think divorce is the worst thing that can happen to them, that divorce is a disgraceful occurrence, and that women leave their husbands as a last resort. Why therefore did these two women leave their husbands? The husband of woman A went to work outside the watershed for several years, but failed to send money for family support. Woman A needed money and assistance, but did not trust her husband, suspected that he had another woman elsewhere, and had to do all the agricultural work, childcare, and housework herself. An old man took advantage of her very difficult position and had an affair with her. This was discovered by her husband's family who then beat her. Local people said she was very ashamed, could not face life in the village anymore, and escaped. She has never gone through divorce procedures. Woman B had a very unsatisfactory marriage. She is a capable, hard-working, and pretty woman, but her husband was incapable and lazy—informants recorded that "he could not do anything at all very well"—with the result that their life was very poor and unhappy. Finally, the woman left. Neither husband nor wife thought that divorce procedures were necessary. In Wangjia village, no divorced woman lives in the husband's village—divorced woman prefer to leave.

These two women left their husbands stealthily like criminals and took nothing with them. Both were unaware of their right to be a legatee of their husbands. Although in theory China's legal system protects the personal rights of women, as well as their legitimate property and equal inheritance rights, this has little influence on everyday life and decisions in rural areas, where traditional logic and customary practices dominate. The traditional customs stem from patrilineal, patriarchal family values. In practice, women's rights to land and other property in rural areas are not the same as the rights of men. The practice of sending daughters away to marry men in other villages immediately places them in unfamiliar communities and a disadvantaged situation. They have no allies and supporters in their new communities. The husband's family and kinsmen can easily deny the new wife her legal rights.

Strengthening rural legal rights and impartial law institutions is only one aspect of the changes that are clearly required. The most important point is to support measures to increase the levels of literacy and education in legal matters among women. These levels must be as high or higher than the levels of education of men if women are to participate actively in social and political institutions. Women must have enough confidence and education to speak out in defence of their rights.

Improving Access to the Education System: A Decade of Progress

Although the educational levels of young women are much better than those of older women, the levels of literacy and education in legal matters remain inadequate. Of the 17 women interviewed between the ages of 34 and 44 years:

- four had never spent a day at school and were completely illiterate;
- five had entered but dropped out of primary school—one staying for only half a year;
- eight had studied for five years and graduated from primary school (primary level schooling now has six grades); and
- two had entered junior middle school, one graduating at 3rd grade.
- None of the 17 had entered high school.

The woman who was educated the longest is both the director of the local women's group and the village doctor. It is a good example. The more schooling received, the more positive a woman's attitude to her own work and her role in the family. Most women over 50 are illiterate.

Although the level of female education in China has made great progress in recent decades, in Wangjia village men are still consistently better educated than their wives. Two of the women interviewed who had never been to school did not know the level of their husband's education—they said they had never asked and were not interested in school or education level. One of these women was actually the wife of a junior middle school graduate who is now a primary school teacher. Of the remaining 15 husbands, all were literate. Three had stayed in primary school for between three and four years and then dropped out; twelve had stayed for five years and graduated from primary school; and of these, eight had entered junior middle school, six staying for one to two years before dropping out. Two men had graduated from junior middle school and entered high school to study, but neither had graduated from high school.

The men had clearly received more education than the women. Wangjia village residents generally thought that boys must be literate, but for girls it depended on the wealth of the household. It was thought ideal if they could afford to send girls to school, but boy's education was considered first.

The state government has introduced programmes for eliminating illiteracy at all levels, and basic literacy classes and schools have been set up. Many young and middle-aged women who had not previously been provided with the chance to go to school have since learnt reading, writing, and basic arithmetic skills in this way. Some middle-aged women find studying very difficult because they think they are too old to learn. It is very common for a 45 year-old woman to be a grandmother, and these young grandmothers feel they are very old in their ideas. A woman who had previously attended night school told the interview team: "I was so sleepy when I took up the books at night. A day's work in the house and fields is very tiring. I am too old to understand and remember the complicated and deep things that the teacher tells us. Even if I learned something during the class, I forgot it after several weeks. Reading and writing are more difficult than doing all the agricultural work." Having completed the literacy classes, women generally have neither the time nor the energy to make reading or writing a habit, and they find it easy to forget the knowledge they received at school. Eventually, they become illiterate again. The success rate in eliminating illiteracy in the older age groups is therefore very low.

Nevertheless, educational opportunities have improved markedly for the young. All levels of government have carried out steps to meet the objectives of the Compulsory Education Law of the People's Republic of China, which has made education compulsory for children of school age. In Wangjia village there is a new primary school. In comparison with other schools in Yunnan Province, the facilities are excellent. The children have a new three-storey building with new desks and chairs. The school was funded by the education department of Baoshan city, the village administration, and the villagers. It has seven classes, one preparatory and grades one to six, and seven teachers (one female). Four of the teachers are graduates from a teacher training school, and three have graduated from junior middle school. All 104 children of compulsory school age in Wangjia village attend the school, and all must graduate.

An illustration of the recent change in attitudes toward education is that some parents are becoming concerned about the quality of the education provided: "the building may be good but the children's scores in the graduation examinations were not good relative to those in other schools in the area". The parents believe that the main problem is the quality of the teachers and their teaching methods. Most parents like to send their children to school, and hope that in the future their children will be able to find non-agricultural work in the city. Only a few parents are unwilling to send their daughters to school, but the law is the law and they must comply. According to the village rules, if parents do not send their children to school, the parent's names are announced over the village loudspeaker and they have to pay a fine. Primary schools are therefore well attended.

Problems arise, however, after primary school. At present, 20 per cent of the Wangjia village children drop out after primary school, although 80 per cent continue to junior middle school in Qingshui township. More than half those who don't continue to junior middle school are girls. The most important reason given by the parents is cost. The cost of putting one student through middle school is RMB 1,500 per year, and it is clear that some families really cannot afford this.

In order to send sons to school, daughters are often asked to leave and return home as boys are considered to be more important than girls in terms of a family's future. Traditionally, educating a daughter is considered to be an investment for 'outsiders'. Although ideas have changed, most of the villagers still prefer to bring daughters home so that sons can continue their education. Another problem is the unsatisfactory examination results of some girls at the middle school. Girls in primary school record better results than boys—girls are thought to study harder than boys at this level and to be more responsible and obedient. However, at middle school boys are considered to develop faster and some girls have trouble keeping up with them. This leads many people to believe that girls are not as intelligent as boys, although others realise that girls have extra responsibilities at home which demand early mornings and late nights, and that they often undertake the mother's role at home. During special occasions or emergencies, parents always rely on these 14-15 year old girls.

In conclusion, the government's efforts at improving education facilities for all children, especially for girls in mountain areas, has resulted in enormous improvements. However, the level of literacy is still lower for girls than for boys, and daughters are still disadvantaged in terms of access to education. In Wangjia village, improvements are required in the quality of the teachers and the teaching methods, and this will require greater investment and continued change in long-held traditional ideas.

Health Care: A Combination of Traditional Practices and Modern Medicine

There is one primary health centre with one male doctor for the whole of Wangjia. The resources of the centre are not sufficient to meet the needs of the local people. There are three other private doctors (one female and two male), but they do not work in the primary health centre. These private doctors began practising in the village a few months after completion of training and none have received formal medical training from a school or college.

Mrs Wan Guoqiong is the private female village doctor and director of the village womens' group. She is responsible for the promotion of family planning in the village and has attended three training courses (three months) on family planning and women's health. She began practising medicine as a private doctor using the knowledge from these short training courses and a simple, easy to read medical book. Her entire medical equipment fits in a box, which she takes with her on house calls. She earns about 200 RMB per month as a doctor. She has three kinds of work and income—doctor, cadre, and farmer. Despite her hard work and dedication, there is a clearly an urgent need for more modern medical equipment and more professional staff.

Mrs Wan Guoqiong said that most women suffer from gynaecological problems because they pay little attention to hygiene. Twelve of the 17 women interviewed had experienced induced abortion or miscarriage. One woman had had 10 induced abortions. The women are responsible for family planning, and the most common methods used are IUDs and sterilisation. As in other areas, there are many failures with the IUDs. Women think their husbands are more important because they are responsible for heavy work, and therefore agree to have an IUD inserted or undergo sterilisation themselves. Formal hospital facilities are far away from the village, thus gynaecological diseases are not uncommon.

All of the 17 women gave birth to their children at home attended by a village doctor or midwife, rather than in a local hospital. They did not use the hospital because of the cost and the long distance. Hospital visits to see a formally educated doctor in Baoshan City are made only when absolutely necessary. The women handle minor health problems like colds and fever on their own, using traditional methods of self-cure. Many of the village women know some common herbal remedies. If traditional remedies do not work, they see the village doctors to get western medicines or injections.

There is a very high rate of parasitic disease in the village, at least in part because of a special food prepared when guests are coming and at times of festivals, weddings, and funerals. This special dish is raw meat with vegetables, hot peppers, ginger, and seasonings. Although delicious, the parasite problem is so severe in some cases that people have died after eating this raw meat dish. Some villagers suffer permanently from parasitic infection, with secondary anaemia and undernourishment.

When women cannot or do not want access to modern medicine, they turn to the local traditional doctors for help. There are two 'witchdoctors' and one 'sorcerer' in Wangjia village. The two 'witchdoctors' have been established for a long time and are often invited to see patients, mostly women, who find themselves in a tight corner. The two women are rarely at home and hardly take any part in agricultural work. The 'sorcerer' is 24 years old and has just started up in his chosen profession. He is not as famous as the two 'witchdoctors' and is still an active farm worker. He earns about RMB 100 per month, whereas the two 'witchdoctors' can earn between RMB 300 and RMB 500 per month plus gifts and payments in grain, meat, oil, and chicken. The 'witchdoctors' are more experienced, knowledgeable, and worldly-wise than most rural woman. A special proverb warns women not to go on long journeys: "Young women are leaving, rumours and slanders are coming". Two of the 17 women interviewed had never been to Baoshan, 25 km from the village. Such cultures, traditions, and beliefs place the witchdoctors in an advantageous position. The local women believe in the witchdoctor's craft. It is said that when a witchdoctor sings and prays, gods and ghosts come into her body, and that it is these gods or ghosts that talk to people about their illnesses and problems rather than the witchdoctor. The witchdoctors often ask for more money and food on behalf of the god. Thus it is easy for a witchdoctor to reap profits from these rural women, who very rarely visit a real doctor in a formal hospital. Some illnesses become more serious as a result of this tradition.

Although the government has several policies aimed at guaranteeing the health of mothers and children, it does not have sufficient funds to train community health workers and improve medical facilities and equipment. While city women enjoy medical check-ups before marriage and during pregnancy, rural village women cannot even obtain formal medical care during birth. Poverty often results in poor nutrition and health care, and traditional customs have a great impact on health, especially that of women and children. The poor, and particularly women, avoid high-priced modern medicine, and turn to the witchdoctors as an alternative.

Decision-making

Most rural areas in China are patrilineal and patriarchal and follow the practice of sending daughters to live with their husbands in other villages and with other communities. For the young women, it is difficult to speak in front of the husband's family, especially in the early days. As a newcomer, a bride is often quiet, silent, and obedient, partly because she is not familiar with the new community and family, partly because it is a custom that she should follow. Before marriage, a bride is taught how to get along well with the new members of the family, and the appropriate behaviour, demeanour, and attitude towards the husband, parents-in-law, and other relatives. The most important principle to learn is how to avoid offensive benaviour to anybody in the family or community. She should respect her father and mother-in-law, and the other old people in the community. A common saying teaches: 'quietly immerse yourself in hard work, silently lower your head beside the dinner table'. Speaking loud and especially making decisions like a man in front of the husband and husband's parents are thought impolite and unreasonable. The incoming bride has a lower status and is rarely permitted to express her own ideas and opinions. Decisions are taken by her husband and the husband's relatives. After a young woman has lived in her new family for several years, she should have formed a good relationship with the members of the family and community. She will have some supporters and allies who will help her to express her own ideas. She can then begin to suggest options in family meetings. However, even if a young woman has set up a good support group within the family, she cannot count on anybody listening to her. When a woman and her husband split from the joint family, the situation is different. It is easier to express her ideas and provide ideas and suggestions to her husband especially in the home. Decision-making systems vary from family to family and it depends somewhat on the personality and capability of a woman relative to her husband. As families become smaller, women's decision-making rights are improving. Men and women were asked who had the most influence on decisions in different areas. The results are summarised in Tables 14 and 15.

Table 14: **Evaluation by Men's Group of Balance in Decision-making between Men and Women in Wanjia Village**[a]							
	Farm Activities	Expendi-ture	Children's Education	Care of Elderly	Birth	See a Doctor	House-work
Men	8	8	5	9	5	5	1
Women	2	2	5	1	5	5	9
Note: the higher the number the greater the decision-making responsibility, 10 is the highest score							

Table 15: **Evaluation by Women's Group of Balance in Decision-making between Men and Women in Wanjia Village**							
	Farm Activities	Expendi-ture	Children's Education	Care of Elderly	Birth	See a Doctor	House-work
Men	5	7	5	8	5	5	2
Women	5	3	5	2	5	5	8
Note: the higher the number the greater the decision-making responsibility; 10 is the highest score							

Overall, men and women had a similar view of the degree of responsibility each had for decisions, although men believed they had more power over decisions related to agriculture than did women. The mens' ideas appear to follow the traditional idea of what men should do and how they should behave, whereas the womens' point of view appears more related to actual practice. Supporting the aged and arranging funerals are two big items that are decided mainly by the husband's family, with the husband and his brothers playing a key role and the women a background role. Selling or buying expensive items like cattle, house materials, big pigs, and machinery are decided mainly by men, as they think that they have more information about price and the quality of goods. As men have more chance to go out of the village, this is in most cases true. Women are permitted to make decisions on buying and selling of small items like chickens, mushrooms, tea, and daily necessities. Sending children to school, seeing doctors, and aspects of birth are decided jointly by men and women. Women decide about almost all aspects of housework and the daily life of the family. In 80 per cent of households, women keep the money according to the traditional custom which follows the proverb: "a woman is a dam, a man is a river." This was explained by an elderly lady—a women is thrifty in running her home and accumulates money like a dam, but men are the source of family income like a river. However, a bad dam cannot hold back water, even if the river pours a lot of water into it. Thus, although women keep the money, the men still control it.

Young people tend to decide who they wish to marry. Parents might suggest and cajole, but their real role is in arranging the chosen marriage. The parents of both sides meet with two matchmakers and discuss (several times) how much the boy's family will give the girl and the girl's parents to cover the bride price. At present, the bride price is RMB 4,000 to 6000; this is divided into two shares, one for the girl, one for the girl's parents. The girl's share is brought to the husband's family as the girl's own property.

Thus it seems that women play an active role in the planning and management of cultivated land and the family economy, and mothers play an important role in sending children to school and seeing doctors, and control the daily life of the families, but the character of decision making in the village is that the more important the decision, the less the control the women have.

Participatory Assessment of Resource Use in the Xizhuang Watershed

Yang Yongping[1], Andreas Wilkes[2], and Xu Jianchu[1]
[1]Kunming Institute of Botany, Chinese Academy of Sciences
[2]UN Volunteer, Yunnan PRA Network

Abstract

Local farmers in Xizhuang watershed used participatory assessment to identify many problems in the use and management of natural resources. Almost all residents in the watershed face shortages of drinking and irrigation water to differing degrees. Some potential solutions and alternatives for water resource management were considered. External financial and technical support would be needed for the construction of drinking water supply and water harvesting and irrigation systems. The shortage of farmland is another challenge for local planners. Some farmers hope to develop marginal mountain areas and wastelands for fruit tree orchards and tea gardens to help meet the demands of the rapidly increasing population for food. Other widespread concerns are the stabilisation of existing farmland; the reduction of damage from landslides, floods, and gully and mudflows; the control of soil erosion and improvement of soil fertility; the introduction of high-yield crop varieties; the control of crop pests and diseases; construction or improvement of irrigation systems; and development of agroforestry systems. Off-farm employment is an important source of cash income. PARDYP and other agencies are asked to provide more technical support and assistance for tea garden development and processing, and community forestry management. Capacity building of local institutions and organisations is also of great importance to future development.

Introduction

The People and Resources Dynamics Project (PARDYP) was set up to improve understanding of the environmental dynamics and the use of resources by local communities in the middle mountains of the HKH region, using five selected watersheds as an example. During the past three years of project implementation in the Xizhuang watershed, near Baoshan in the west of Yunnan Province, China, researchers from different disciplinary backgrounds and institutions have undertaken a series of research activities to provide information about the present situation and to monitor changing processes related to natural resources. Some interesting and significant findings have been obtained relating to resource management in the watershed. However, most of the project activities in the region were designed using a top-down approach. These activities often failed to address such questions as: what do the local people consider are the main resource management problems; what are the constraints, gaps and opportunities in knowledge; and what are the key areas in need of future research? These questions had to be answered to help PARDYP to design the activities for the next phase of the project. For this reason, a group of multidisciplinary professionals were trained in participatory needs assessment techniques, and a participatory survey was conducted in Xizhuang watershed in August 1998. Special attention was paid to facilitating local people to identify and discuss their problems and constraints regarding resource use and management, and to ascertaining potential opportunities that could contribute to sustainable development and environmental protection.

The Xizhuang watershed is located in the northwest of Banqiao Township, Baoshan City. There are 3 administrative villages in the watershed—Xizhuang, Qingshui, and Lijiasi—each comprising a number of natural villages.

Xizhuang village is situated at the lowest point of the watershed (1,400 masl) 18 kilometres from Baoshan City, with relatively convenient transportation because of its location on the margin of the Baoshan Basin. The total population of Xizhuang is 1,800. Local farmers traditionally manage paddy fields and upland fields and cultivate paddy rice, maize, and wheat. Small-scale fruit orchards are scattered around the village settlement, but there are only small patches of pine forest remaining within the village area. The main challenge for development in Xizhuang village is the limited farmland area for a large population. Almost all households employ extra labourers who come from outside the village.

Qingshui village is located in the middle of Xizhuang watershed (1870 masl), 23 kilometres from Baoshan City and 12 kilometres from Banqiao Township. Its population of 2,414 people traditionally manage upland fields and cultivate maize and wheat. The farmers have larger areas of forest land than do those in Xizhuang.

Lijiasi village is located in the upper reaches of the Xizhuang River, 24 kilometres from Baoshan City and about 2 kilometres from Qingshui village. As in the adjoining Qingshui village, the local farmers mainly cultivate maize and wheat in upland fields. A large area of pine forest has been preserved and managed around this village. Because of the limited amount of farmland available (0.5 *mu* or about 0.03 ha capita), most households have to buy some food grain in the market. Cash for this is raised by selling tea or working outside the village.

The Participatory Survey

The survey process was divided into three main phases: preparation before fieldwork, field survey and discussions, and information feedback in the field. A three-day workshop was held in Kunming before the fieldwork started. Andreas Wilkes, a UN volunteer with the Yunnan PRA Network, gave a training course on participatory methodologies which was attended by 15 participants. The training focused on the concept of participation and its application in development and research projects. Other aspects covered the facilitator's attitude and behaviour, and the application of certain PRA tools. In the context of the Xizhuang watershed project, the most important outcome of this workshop was that all participants reached a common understanding that the purpose of the participatory assessment was to identify problems, constraints, and possible solutions from the perspective of the local people, rather than to gather baseline data as the researchers had done in the past.

On the first day of the fieldwork, the participants were divided into three groups. All three groups spent a half day in Xizhuang Administrative Village in order to increase their familiarity with the application of participatory tools and facilitation skills in a real-life context. Thereafter, the three groups were assigned to work one each in each of the three administrative villages in the watershed—Xizhuang, Qingshui, and Lijiasi. From the second day onwards, the assessment teams held discussions with different groups of villagers on different topics such as land use, forest resources, water resources, and farming practices. The discussions enabled different groups of villagers to identify key problems and constraints. A variety of PRA tools was used including resource mapping, transect walks, focused discussions, matrix scoring, seasonal calendars, social mapping, and wealth ranking. After two days, the teams returned to Baoshan where they shared their findings and experiences and prepared for a final meeting in each village.

On the fifth day, each group made feedback presentations of their findings to larger groups of residents in each village. The meeting was used to clarify issues with the local farmers and to prioritise the problems and constraints identified by the villagers through a system of matrix scoring or voting. Subsequently, the assessment teams discussed their experiences with PRA and reviewed the strengths and weaknesses of the survey. Details of the participatory assessment exercise are given in Appendix A. The problems identified and prioritised by local farmers are presented in Appendices B, C, and D.

Findings

The local farmers identified many problems that constrain future development. The local farmers are quite knowledgeable and had already realised that one of the main underlying reasons for resource degradation was the rapid increase in population. In order to meet demands for biomass production and to improve the quality of life of local residents, they have had to expand their cultivation into more marginal areas and develop new forms of livestock husbandry. However, these activities exacerbate environmental degradation processes, which have resulted in intensified soil erosion and even some natural disasters. The local farmers can find the solutions for some problems, but to be fully effective, these solutions need an integrated and systematic watershed approach. In some cases, external support and inputs will be essential. No solutions were suggested for some problems because of the large number of inter-related constraints, and the farmers still have to discover alternatives for these. The problems identified during the participatory survey that are of common concern in the Xizhuang watershed are summarised below.

Poor Irrigation and Water Management

Almost all the residents in Xizhuang watershed are facing water shortages for both drinking and irrigation. Springs are the main source of drinking water in the watershed. Since most villages are located on mountain slopes, the collection of drinking water is a great burden for family members, especially women. For example, the villagers in Ganwangkeng, Xiaozhai of Damaidi, and Wangjia village identified the supply of drinking water as the top priority since they have to spend a lot of time each day collecting it. In other villages local farmers face water shortages in the dry season and can only obtain muddy water during the monsoon. However, since the construction of drinking water and irrigation systems requires a large investment, the problem is difficult to solve at present. PARDYP is planning to build a drinking water supply system in Ganwangkeng.

Throughout the whole watershed, lack of irrigation water is an important constraint to increasing the yield of agricultural production. In Damaidi, for example, local farmers have to collect water from distant springs to water their maize seedlings every March and April. The local farmers hope that PARDYP and other agencies can help them construct some mini-tank water harvesting systems.

In contrast, in the downstream reaches of the Xizhuang River and in Qingshui village, floods in the rainy season lead to losses of farmland, destruction of crops, and road damage. Local farmers expressed a strong desire to dredge the river and canals, to construct river banks, and to plant trees for flood control.

Insufficient Farmland and Poor Soil Fertility

As a result of the rapid increase in population, there is a shortage of farmland throughout the watershed. At present, the area of farmland per capita is less than 0.07 ha. Farmers in different villages suggested different solutions to the problem. In Xizhuang village, local residents hoped to use a large area of wasteland for agricultural cultivation. The villagers in Wangjia of Lijiasi Administrative Village planned to develop fruit tree plantations on mountain slopes. Both these solutions would need capital and technical support. A significant number of villagers disagreed with these suggestions as they believed that extending cultivation to marginal and steep areas would result in intensive soil erosion and low yields in the absence of significant fertiliser inputs. Other solutions suggested for the shortage of farmland were to stabilise existing cultivated lands through landslide and flood control measures, to increase soil fertility, to develop agroforestry systems, to introduce high-yielding crop cultivars, and to improve local irrigation systems. For some households, off-farm employment is an important alternative means of increasing income and thus alleviating the food shortage.

Forest Resource Management

Most of the pine forest plantations in the middle and upper reaches of the Xizhuang River are well protected and managed through effective locally-established regulations. They provide the villagers with sufficient firewood for their daily lives. At present, some farmers hope to extend the use of grassland areas for livestock husbandry. However, in the downstream of the watershed, for example in Xizhuang village, the local residents face serious shortages of firewood, and hope to install energy-saving stoves and develop community forestry to meet their multiple needs for firewood, fodder, and cash crops (fruit trees). Most barren slopes and wasteland are highly degraded as a result of long-term soil erosion, so that any form of reforestation and afforestation will be difficult and time consuming. Local farmers expressed strong hopes that PARDYP would support their reforestation initiatives through technical support for nursery development and forest management.

Tea, Plantations and Processing

Tea is the most significant source of cash income for many villagers in the watershed. The local farmers expressed considerable concern about their tea plantations. The problems that need urgent solution are low production, poor processing techniques, and lack of equipment. Most tea gardens were planted before the 1970s, so new tea varieties and adequate inputs could have a profound impact on the tea yields. Furthermore, the prevalent traditional manual method of tea processing lowers the quality of the tea and limits the market potential. PARDYP is planning a training workshop on tea cultivation and processing in Xizhuang watershed in the coming year. Another option is to establish some tea nurseries and demonstration sites to disseminate to local tea farmers essential information and techniques on breeding and grafting of quality tea varieties, management of tea plantations, and processing of tea.

Pest and Disease Control

The widespread incidence of pests and disease is an important factor leading to low yields. The farmlands have been managed by individual households since the 1980s, making the control of pests and diseases more difficult than formerly under the collective system. Insecticide and pesticide sprays are largely ineffective as a result of individual decision-making and diverse application techniques. At the same time, many farmers recognised that the use of insecticides and pesticides is associated with environmental pollution, which presents a serious threat to the local livestock husbandry. In Damaidi, for example, local dogs, cats, chickens, and even horses have died because of the extensive use of poisonous pesticides. Many farmers expressed concern about the safe use of insecticides and pesticides. Some essential technical support and training on pest and disease control are urgently needed in the watershed.

Building Up of Local Institutions and Organisations

Local organisations, particularly at the administrative village level, have played an active and positive role in the use and management of natural resources. For example, Lijiasi Administrative Village has established some effective regulations to encourage the development of community forestry and to control grazing. Local government agencies have also made considerable contributions to education and infrastructure. However, more efforts are needed to improve local institutions and organisations. Many problems which local farmers consider important are closely related to inefficient or ineffective local institutions. Villagers in Ganwangkeng and Xiaozhai of Damaidi complained that local organisations could not implement drinking water and irrigation projects even though they had made some investments. The residents in Xizhuang village accused the village leaders of renting out their community-owned tea garden and eucalyptus plantation to some households, which had exacerbated local firewood shortages. They were eager to formulate some local regulations for the development and management of the community forest and other common properties. Effective solutions for some problems, such as the pollution from the Xizhuang Cement Factory, the conflict between the Xizhuang and Baoshan Waterworks on drinking water irrigation, and the control of stone/gravel extraction from the Xizhuang watershed, will depend largely upon the efforts and capacities of the existing local organisations.

In conclusion, the participatory assessment survey enabled local residents to identify many existing problems and at the same time encouraged and helped them in the search for potential solutions and alternatives. PARDYP realises that these solutions demand an integrated approach, which is also the view of many local farmers, and special attention will be paid to developing this during the next phase of the project. PARDYP is now planning to use the research findings on water, forestry, and soil resources for environmental rehabilitation and economic development of the watershed. In Phase II, more emphasis will be placed on technical training, such as that related to tea production and processing, water harvesting, and soil fertility improvement, and on the capacity building of local institutions and organisations.

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Appendix A: **Details of the PRA Visit to Xizhuang Watershed**

August 9: Arrival at Baoshan City, stayed at Baoshan Orchid Hotel

August 10: In the morning, briefing on the overall background of Xizhuang watershed and introduction to the objectives and progress of PARDYP. Discussion was focused on how to approach farmers, how to tell them openly what PARDYP can and cannot do, and how to avoid raising their expectations. In the afternoon, all the participants visited Xizhuang village and made friends with farmers or made appointments for the next day's PRA exercises.

August 11: After the warming-up of the previous afternoon, the three groups easily found the farmers and held discussions to identify problems. Social mapping needed more time, but each group finished resource mapping and seasonal calendars before noon. At lunchtime the participants reflected that most of them had found it difficult to 'hand over the stick to villagers', but that nevertheless it was easy to facilitate farmers to identify and analyse the problems they were facing and to discuss some possible solutions and alternatives. In the afternoon, each group presented their findings in the village, and a meeting was held with the village leaders to report and discuss the problems identified by the farmers.

August 12: The three groups were each assigned to a different administrative village area. The group in Xizhuang village continued, using the results of the previous day's exercises as a basis. The farmers were helped to carry out matrix scoring of the problems already identified (see Appendix B). Eleven problems were identified that local farmers saw as of widespread concern in the village. Two further problems were added: village infrastructure construction and pollution from the Xizhuang Cement Factory. The group assigned to Qingshui Administrative Village, led by Ms. Qian Jie, visited Ganwangkeng village, and organised local farmers to identify their main problems by means of resource mapping and social mapping (Appendix C). The four team members sent to Lijiasi Administrative Village visited Wangjia village. Some of the main problems of this village were identified using focused discussions (Appendix D). The team members then used a resource map drawn by the farmers to promote more widespread discussion among the villagers. A primary school teacher and a local medical practitioner were invited as key informants to help understanding of the local education and medical services.

August 13: The group in Xizhuang village, used the list of 13 problems to help farmers to carry out problem ranking. Five problems were finally determined to be of relatively greater importance. More farmers and village leaders were invited to discuss possible solutions to these problems. The group in Qingshui Administrative Village visited Qingshui natural village and continued to facilitate farmers to analyse the main problems constraining local development (Appendix C). In Lijiasi Administrative Village, the team members visited the most remote village in Xizhuang watershed, Damaidi natural village. Problems and potential solutions or alternatives were identified and determined by the villagers (Appendix D).

August 14: Each group prepared their feedback presentations in the Baoshan Orchid Hotel in the morning. In the afternoon the Xizhuang village group returned to the village to present their findings and ask farmers to prioritise the problems, taking advantage of the fact that many villagers were meeting in the village temple for a religious ceremony that day. The Qingshui Administrative Village group organised a village meeting attended by over 50 people to prioritise the problems identified.

August 15: The group assigned to Lijiasi Administration Village gave a feedback presentation in Wangjia village. After discussion among village representatives on the problems and potential solutions, matrix scoring was used to prioritise the problems.

Appendix B: **The problems identified by farmers in Xizhuang Administrative Village**

- Serious crop pests and diseases
- How to use existing wasteland
- How to control soil erosion
- How to improve land productivity
- How to increase the sources of cash income
- How to improve village settlement planning
- Heavy burden of fees for education
- Poor medical service
- Less organised social institutions
- Different awareness and perception of natural resources
- How to improve agricultural extension
- How to improve the efficiency of energy-saving stoves
- How to use farmland effectively and improve the local cropping pattern
- How to improve the family education of children due to off-farm employment
- How to deal with serious flood and soil erosion in the Xizhuang River
- Conflicts of land tenure
- How to improve local reforestation
- How to improve local husbandry
- How to improve soil fertility
- How to disseminate information on agroecology
- How to get marketing information for local products
- How to deal with the local firewood shortage
- How can rich farmers help poor farmers

After the first matrix scoring by local farmers, 11 of these problems were determined to be of wide concern in the village and some potential solutions identified. They are listed below. Two further problems were added: how to improve village infrastructure construction and how to control the pollution from the Xizhuang Cement Factory.

- Crop pests and disease control
- Developing the potential of wasteland
- Soil erosion control throughout improved farming systems
- Diversifying the sources of cash income
- Lightening the burden of education
- Solving local firewood shortages by means of promoting the energy-saving stove project
- Solving conflicts of land tenure
- Community-based medical services
- Extension of agricultural technology
- Flood and soil erosion control in the Xizhuang River through planting fruit trees
- Off-farm employment and children's education

- Village infrastructure construction and irrigation system renovation
- Pollution control

The farmers were asked to rank these problems in terms of priority. The following five problems were finally determined by farmer representatives to be the most important problems that needed to be solved.

- Village infrastructure construction, especially road construction within the village and renovation of the irrigation system
- Extension of practical agricultural technology
- Flood and soil erosion control of the Xizhuang river
- Developing non-timber forest products, such as fruit trees, tea, and mulberry
- Improving soil fertility

Appendix C: **The problems identified by farmers in Ganwangkeng and Qingshui, Qingshui Administrative Village**

Ganwangkeng

- Drinking water supply
- Water supply for agricultural irrigation
- Low yields of crops
- Low yields of tea
- Low productivity of farmland
- Landslides
- Floods
- Lack of grasslands for livestock
- Low education
- Road construction

The farmers performed matrix scoring and identified two problems of widespread concern: drinking water supply and road construction. The farmers also expressed a strong desire to improve soil fertility and the yields of maize, wheat, and tea. The supply of irrigation water, agricultural extension, and increasing the amount of grassland were of less importance.

Qingshui

The above list was supplemented by the following problems highlighted by the farmers in Qingshui natural village.

- Lack of water for agricultural irrigation
- Floods, landslides, and some disasters
- Road damage as a result of river erosion

Appendix D: The problems identified by farmers in Wangjia and Damaidi, Lijiasi Administrative Village

Wangjia

- Limited farmland and low soil fertility
- Low productivity of tea gardens and outdated tea cultivars
- Poor techniques for tea processing
- Poor supply of drinking water
- Difficulty in the development of fruit tree plantations
- Serious crop pests and diseases

Damaidi

The above list was supplemented by the following problems highlighted by the farmers in Damaidi, Lijiasi Administrative Village.

- Land tenure conflicts with other villages
- Low production of crops due to low soil fertility, low temperature, and low sunlight
- Lack of a drinking water supply, especially in Xiaozhai
- Lack of water for agricultural irrigation
- Serious damage by rats and some negative impacts of rat control

Population Dynamics and Land Use in the Yarsha Khola Watershed

Bhuban Shrestha
PARDYP, MNR/ ICIMOD

Abstract

The increasing population is putting pressure on local natural resources leading to rapid changes in land use that seriously affect the long term sustainability of the food, feed, and fuelwood production systems. Aerial photographs were used together with intensive field verification and GIS overlay techniques to quantify the population and land use dynamics in the Yarsha Khola watershed between 1961 and 1996.

The population in the Yarsha Khola watershed more than doubled between 1961 and 1996. This represents an average annual growth rate of 2.6 per cent, higher than the national average. The changes in land use as derived from the GIS analysis showed that the forest area increased between 1981 and 1996 at the expense of rain fed agricultural land and shrub land. The forests were dominated by mixed broadleaf forest (43%), followed by pine (31%), and *Alnus Nepalensis* (22%). However, the forest quality was relatively poor with 70 per cent of all forest having less than 30 per cent crown cover; and 72 per cent of the forest being immature.

Introduction

The Yarsha Khola Watershed covers an area of 5338 ha and is situated between 27° 33' 45" and 27° 40' 00" N, and 86° 05' 00" and 86° 11' 15" E in the middle mountains of Nepal. It is located about 190 km east of Kathmandu along the Lamo Sangu Jiri road (Figure 12).

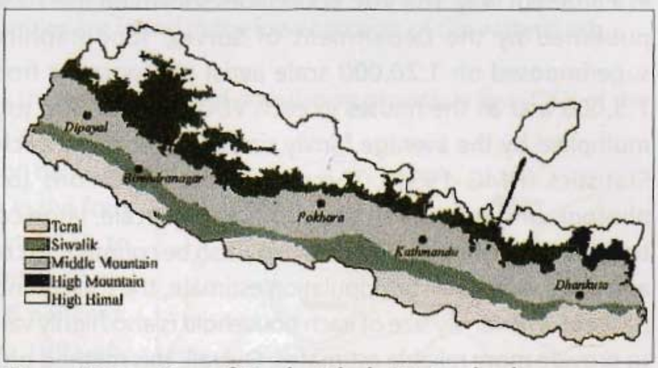

Figure 12: **Locaiton of Yarsha Khola Watershed**

The elevation ranges from 930 to 3030 masl. As a result of the large topographic variability, the watershed contains many areas with distinct micro-climatic conditions that influence the land use systems and composition of the resident ethnic groups. Land use is dominated by agriculture with two annual crops in those areas where irrigation water is available, one to two annual crops in rainfed areas, and three crops grown over a two-year period at higher elevations.

The Lamo Sangu Jiri road, which connects Kathmandu to Jiri, runs through the northern part of the watershed, making it easily accessible.

Objectives

The increasing population is putting pressure on the local natural resources, and this is leading to rapid changes in land use that seriously affect the long term sustainability of the food, feed, and fuelwood production systems. The aim of this study was first to document processes and trends in the Yarsha Khola Watershed (YKW) from 1961 to 1996 through a study of past and present population dynamics, land use changes, and population-land use interactions; and second to analyse the forest situation using a geographic information system (GIS) as an integrating tool.

Methodology

Population

Population information is available once every ten years for each village development committee (VDC) area. The population information for 1971, 1981, and 1991 published by the Central Bureau of Statistics (HMG 1991) was used to show the past trends of population dynamics in the watershed. There are some problems with this information, however, because: a) the VDC boundaries change frequently; b) the data is not clearly geo-referenced; and c) the VDC boundaries do not coincide with the sub-catchment and watershed boundaries.

As no census data were available for 1996, the population data for 1996 were estimated in a different way. The VDC boundaries shown on the 1:25,000 scale topographical maps published by the Department of Survey, Topographical Survey Branch, 1996 were superimposed on 1:20,000 scale aerial photographs from 1996 enlarged to a scale of 1:5,000 and all the houses in each VDC counted. The total number of houses was then multiplied by the average family size determined for each VDC by the Central Bureau of Statistics (HMG 1991). There are some limitations to counting houses from aerial photographs. Because of the photographic scale, large cowsheds, schools, health posts, temples, post offices, and offices may also be counted. To compensate for such errors and to arrive at a more realistic population estimate, the total number of houses was reduced by 10 per cent. The family size of each household is also highly variable so average data were used to provide more reliable estimates. Overall, this method proved to be the most reliable way of collecting population data for 1996.

Land use

Land use data for 1996 were determined from 1:25,000 scale aerial photographs and field surveys. Detailed qualitative and quantitative information about the land surface in terms of land use, landforms, topography, soils, and the drainage network was obtained using three-dimensional stereo images. General land use categories such as irrigated land, rainfed terraces, forestry, grassland, shrubland, and others were delineated on each photograph and additional details were collected during intensive fieldwork.

Land use information for 1961 and 1981 was obtained from the 1961 Survey of India data and from the topographic and land use maps produced by the Land Resource Mapping Project (LRMP 1981). The 1961 Survey of India only defined two classes of land use—agriculture and forest—whereas the 1981 LRMP survey used more detailed land use classes. As a result of the different land use classifications and scales used by the three sources, the land use in 1961, 1981, and 1996 could not be compared directly—but an attempt was made to record the general trends.

Geographic Information System Analysis

All the land use information was digitised into the GIS database and each temporal set of land use information recorded. The total areas and units under the various types of land use were determined from the digital database, and the land use changes over time examined quantitatively using GIS overlay techniques.

Population Dynamics in the YKW between 1971and 1996

There are four VDCs in the Yarsha Khola watershed. More than half of the total area of Namdu VDC is situated outside the watershed, but the majority of Kabre (and all of its population), and almost all of Gairimudi and Mrige, lie within the watershed (Figure 13). The three dominant ethnic communities in Yarsha Khola are Tamang (27%), Brahmin (25%), and Chetri (25%). In general, the higher parts of the watershed are dominated by Sherpas and Tamangs, whereas other communities are found in the lower section of the watershed.

Figure 13 and Table 16 show the population and population growth in the VDCs of the watershed in 1971, 1981, 1991, and 1996, and Table 17 shows the population densities in 1996. The overall population in the four VDCs increased from 10,885 in 1971 to 20,620 in 1996. This is equivalent to an average annual growth rate of 2.6 per cent, which is slightly higher than the 1991 annual national average of 2.1 per cent. The population increased mainly on the south facing slopes in Namdu and Kabre VDCs. There was a lower increase or reduction in the population of the north facing slopes in Mrige and Gairimudi VDCs.

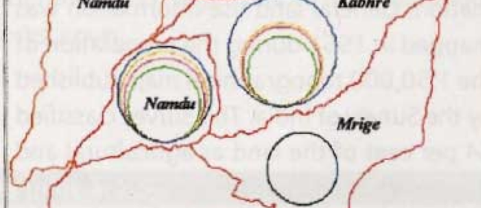

Figure 13: **Population Dynamics (1971-96)**

Table 16: **Total Population of Yarsha Khola by VDC, 1971 to 1996**

VDC	1971	1981	1991	1996	Population Growth Rate 1971-1996 (%)
Gairimudi	4,423	5,584	4,299	4,375	-0.04
Mrige*	-	-	3,216	3,276	0.2 (1991-6)
Namdu	3,431	4,259	4,938	5,357	1.8
Kabre	3,031	3,894	4,235	7,612	3.8
Watershed Total	10,885	13,737	16,688	20,620	2.6
District Total	130,022	150,576	173,236	NA	

Note: The values shown are for the whole of each VDC.
* Mrige VDC did not exist in 1971 and 1981.
Sources: 1971, 1981, and 1991 data from Central Bureau Statistics, HMG, Nepal; 1996 data are estimates from enlarged 1:5,000 aerial photographs

Table 17: **Population Density in 1996 (persons per square kilometre)**

VDC	Total Population	Total Area (ha)	Population Density
Gairimudi	4375	1989	220
Mrige	3276	1324	247
Namdu	1981	667	297
Kabre	7612	1358	560
Watershed Total	17244	5338	331

Note: Except for Namdu, values are for the whole of each VDC. Values for Namdu relate to the part of the VDC within the watershed.

The construction of the Lamo Sangu Jiri Road has had a significant impact on the watershed. The road, which was constructed in the 1980s, passes through the Namdu and Kabre VDCs. The expansion of population in Namdu and Kabre most likely resulted from the road construction, which provided access to markets in Jiri, Naya Pool, Maina Pokhari, and Charikot. There was a significant movement of people from Gairimudi to the other areas following the construction of the road. The largest expansion of population occurred in Kabre VDC, with a 3.8 per cent growth rate between 1971 and 1996.

Land Use

Land use is determined by the climate, topography, soils, and people. Trends in land use were investigated using historical information. General land use information was mapped in 1961 during the preparation of the 1:50,000 topographical map published by the Survey of India. This survey classified 64 per cent of the land as agricultural and the remaining 36 per cent as forest (Figure 14).

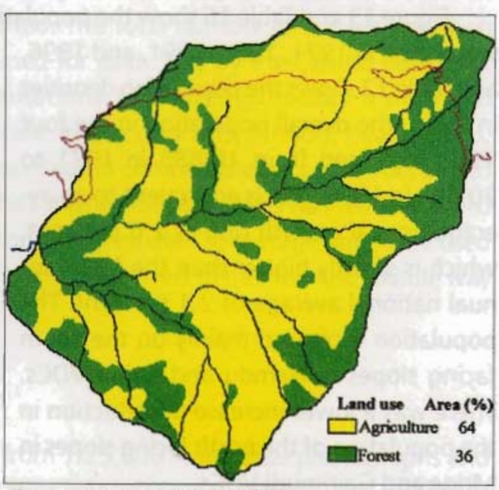

Figure 14: **Land Use, 1961**

The 1980s Land Resource Mapping Project (LRMP) used the same 1961 topographical base map to display more detailed land use data derived from 1:50,000 scale aerial photographs flown in 1979-80. The results are shown in Figure 15. Although the 1961 and 1981 maps were prepared at the same scale, it is difficult to compare the data sets because of the different classifications used. The total amount of *khet* (irrigated agricultural land) and *bari* (rain fed agricultural land) shown in the 1981 map is 65 per cent, suggesting that there was effectively no overall change in land use between 1961 and 1981, and that the category 'forest' used in the 1961 map included the categories 'grass', 'shrub', and 'other land' shown in the 1981 map.

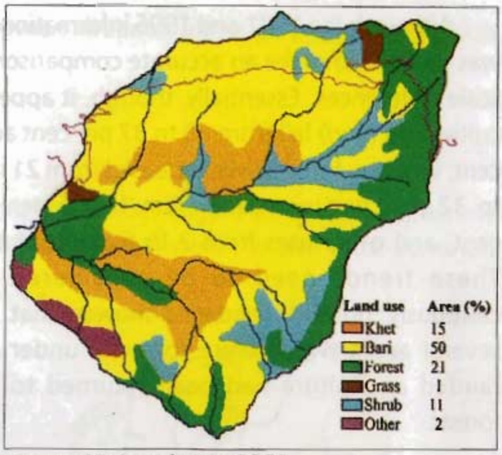

Figure 15: **Land Use, 1981**

A detailed land use survey was conducted by PARDYP using the 1:20,000 aerial photographs from1996. Intensive field verification was carried out to understand the patterns of land use within the watershed. The data were analysed by GIS techniques. The final map is shown in Figure 16. Thirty-two per cent of the watershed was under forest cover, 37 per cent under rainfed cultivation (*bari*), 14 per cent irrigated agricultural land (*khet*), 6 per cent grassland, 5 per cent shrubland and the remaining 7 per cent 'other land cover' (landslides, rills, gullies, settlements, rocks and boulders). Table 18 shows the land use distribution by VDC as generated by the GIS. Gairimudi had the largest total area of khet (irrigated), and Mrige the smallest. Mrige had the largest total amount of forest land, slightly more than Gairimudi, Kabre much less, and Namdu relatively little forest cover.

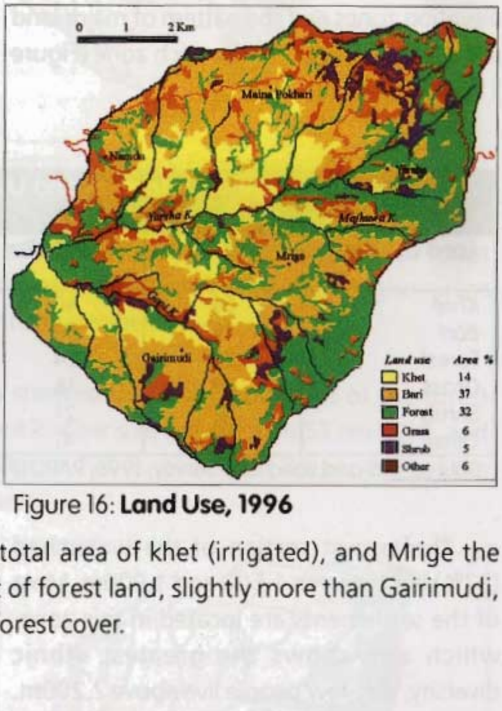

Figure 16: **Land Use, 1996**

Table 18: **Land Use Distribution by VDC, 1996 (area in ha)**

VDC	*Khet*	*Bari*	Forest	Grass	Shrub	Other	Total
Gairimudi	290	768	651	79	84	117	1,989
Mrige	66	417	677	42	66	56	1,324
Namdu	171	240	127	70	4	55	667
Kabre	217	573	226	111	114	117	1,358
Watershed Total	744	1,998	1681	302	268	345	5,338

Although the 1981 and 1996 information sets used the same classification categories, it was difficult to make an accurate comparison of land use at these dates as a result of the scale differences. Essentially, though, it appeared that the amount of land under rainfed cultivation (*bari*) fell from 50 to 37 per cent and the amount of shrubland from 11to 5 per cent; whereas forest cover increased from 21 to 32 per cent, grassland from 1 to 6 per cent, and other uses from 2 to 6 per cent. These trends need to be considered cautiously, but field evidence showed that several areas which were formerly under rainfed agriculture had been returned to forests.

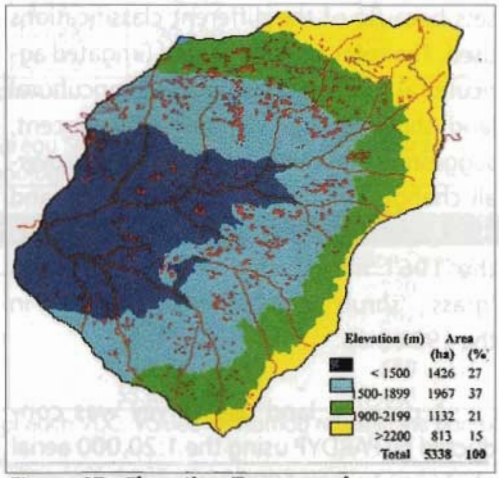

Figure 17: **Elevation Zones and Distribution of Houses**

Land Use by Elevation Zone

The watershed was divided into four elevation zones and the pattern of major land use classes determined for each zone (Figure 17 and Table 19).

Table 19: **Percentage of Different Land Use Classes within the Different Elevation Zones**

Land Use Class	<1500m	1500-1899m	1900-2199m	>2200m	Watershed Total
Khet	59	40	1	0	14
Bari	19	50	26	5	37
Forest	23	24	22	31	32
Grass	48	18	12	22	6
Shrub	8	21	43	28	5
Other	20	41	23	16	6
Source: GIS and Land Use Survey, 1996, PARDYP-MNR/ICIMOD					

The largest section of the watershed (37%) lies between 1,500 and 1,900m. Most of the settlements are located in this zone, which also shows the greatest ethnic diversity, very few people live above 2,200m.

The majority of irrigated (*khet*) land (59%) was located at elevations below 1,500m, whereas half of the rainfed agricultural land (*bari*) (50% or about 1,000 ha) lay between 1,500 and1,899m (Figure 16 and 18).

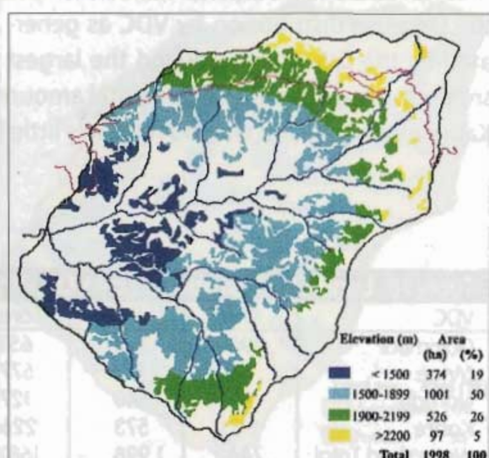

Figure 18: ***Bari* by Elevation Classes**

Forest was almost equally distributed between all zones, although the largest portion was found above 2200m (31%) (Figure 19).

Forest Types and Distribution

The forest was classified in terms of dominant species (Figure 20). *Alnus nepalensis* (31% of the forest area) and pine (23% of the forest area) were the two most common dominant tree species in the watershed.

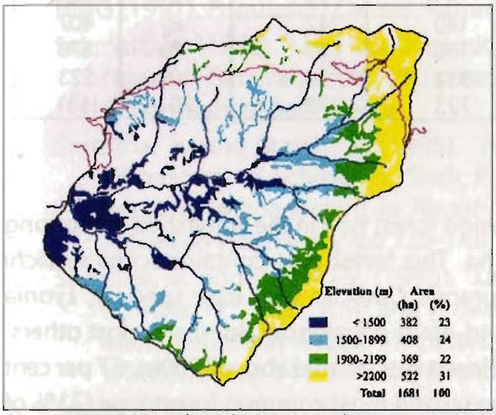

Figure 19: **Forest by Elevation Classes, 1996**

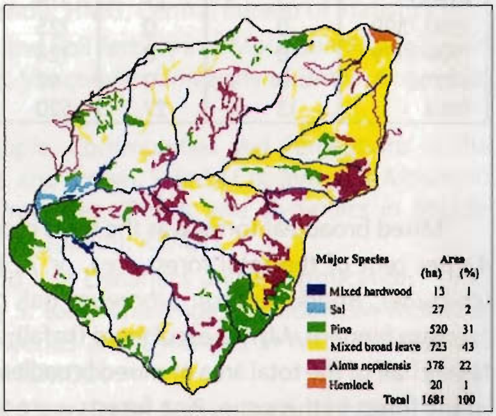

Figure 20: **Major Forest Species, 1996**

The forest was also classified in terms of forest type (Figure 21). Hardwood forest was the most widely distributed and comprised 42 per cent of the total forest area. Mixed forest comprised 24 per cent of the forest cover and was mostly distributed in the higher areas (>2200m) in the north-east and south-east of the watershed.

Classification according to maturity class showed that only 8 per cent of the forest within the watershed was mature to over-mature (timber size greater than 53 cm DBH), and 72 per cent was immature (28-53 cm DBH) (Figure 22). Furthermore, 70 per cent of the forest had a crown cover of less than 30 per cent.

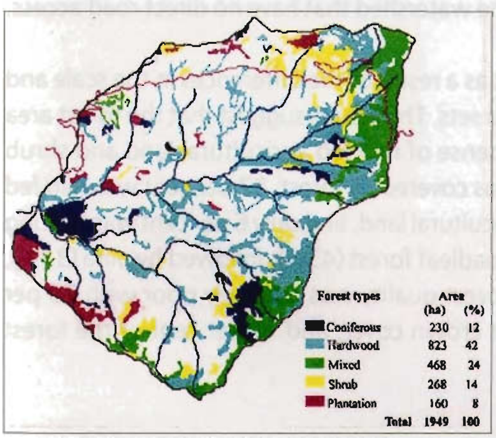

Figure 21: **Major Forest Cover, 1996**

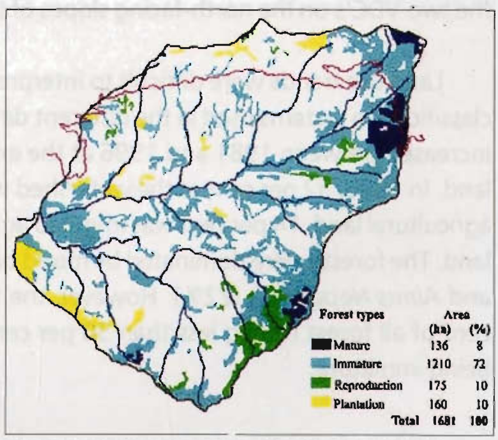

Figure 22: **Forest Maturity Classes, 1996**

Forest Species Distribution by Elevation Zone

The major forest species were overlaid on the elevation zones, and the distribution in relation to elevation examined. The results are shown in Table 20.

Table 20: **Forest Species Distribution by Elevation Zone (ha)**

Elevation	Mixed Hardwood	Sal	Pine	Mixed Broadleaf	*Alnus Nepalensis*	Hemlock	Total
<1500	13	27	174	71	95	0	381
1500-1899	0	0	125	140	142	0	407
1900-2199	0	0	124	160	87	0	370
>2200	0	0	97	352	54	20	523
Total	13	27	520	723	378	20	1681

Mixed broadleaf forest was the most common forest type in the watershed comprising 43 per cent of the total forest area, or 723 ha. This forest type contains *Scima wallichi* (chilaune), *Rhododendron arboreum* (lali gurans), *Quercus spp.* (oak species), *Lyonia formosa* (angeri), *Myrica escuklenta* (kafal), and *Alnus nepalensis* (alder) amongst others. Nearly half of the total area of mixed broadleaf forest was located above 2200m, 67 per cent of the forest in this zone. Pine forests were the second most common forest type (31% of total forest). This was the most common forest type at altitudes below 1,500m. *Alnus nepalensis* was the third most common forest type, 38 per cent of *Alnus* forest was found at elevations between 1,500 and 1,900m.

Conclusion

The population in the Yarsha Khola watershed more than doubled between 1961 and 1996. This represents an average annual growth rate of 2.6 per cent, which is higher than the national average. There were large differences in the distribution of population growth within the watershed. There was a small drop in the population in Gairimudi and possibly in Mrige, the two VDC's on the north-facing slopes of the watershed that have no direct road access.

Land use trends were difficult to interpret as a result of the differences in the scale and classification systems used in the different data sets. The results suggest that the forest area increased between 1981 and 1996 at the expense of rain fed agricultural land and shrub land. In 1996, 32 per cent of the watershed was covered by forest, 37 per cent was rain fed agricultural land, 14 per cent was irrigated agricultural land, and only 6 per cent was grazing land. The forests were dominated by mixed broadleaf forest (43%), followed by pine (31%), and *Alnus Nepalensis* (22%). However, the forest quality was relatively poor with 70 per cent of all forest having less than 30 per cent crown cover; and 72 per cent of the forest being immature.

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Milk Production Dynamics and the Animal Feed Situation in the Jhikhu Khola Watershed

Bhuban Shrestha
PARDYP, MNR/ICIMOD

Abstract

A rapid population increase, an increasing need for cash income, and market opportunities have led to a rapid change in milk production in the Jhikhu Khola watershed in Nepal. Nine years ago a milk collection and chilling centre was established in the watershed and this provided the farmers with the incentive and opportunity to move into the market economy. Previous studies had shown, however, that there is a great shortage of animal feed and that the workload of women is very high. Approximately 80 per cent of the work involved in livestock care is undertaken by women, who are responsible for collecting feed every day. The present day dynamics of milk production and the animal feed situation were studied in detail to determine the rate of change in milk production, and the possible impacts and consequences of a rapid increase in the number of buffalo and the associated increase in demand for feed. The questions the study was designed to answer included: 'How much can the cash flow from milk contribute to easing the feed shortages?' and 'Is it cost effective to use some of the grain produced to supplement animal nutrition?'

All the animals were stall-fed. Crop residues and grass were the two main sources of feed. The majority of winter feed (69%) derived from crop residues, the majority of summer feed from fresh grass. There was a shortage of crop residues from April to July in the spring and early monsoon, and of grass between October and May. Women generally had sole responsibility for collecting grass from agricultural and forested land, although occasionally the whole family helped. Men more commonly collected fodder from fodder trees on private land, and were mainly responsible for the transportation of milk to the cooperative centres.

The farmers purchased water buffaloes in order to make money by selling milk, but they felt they were not able to benefit sufficiently from this activity. They had great difficulty maintaining the buffaloes as they require special treatment and care throughout the day—the work required for one buffalo was considered equivalent to a full time job in the city. As a result of the 25 per cent reduction in the amount of milk accepted by the TCC, 50 per cent of the farmers were forced to use more milk for home consumption than they could cope with. There were few other options for using the milk as there was a lack of fuelwood and water for processing and the poor infrastructure is not conducive to taking the milk elsewhere. Suggestions have been made that the milk be processed into other products, but at present this does not appear to be viable because of the lack of fuelwood, poor infrastructure, poor transportation network, and poor market access. Half of the farmers said that they didn't know how to cope with the milk surplus although some did make ghee (clarified butter).

Introduction

A rapid population increase, an increasing need for cash income, and market opportunities have led to a rapid change in milk production in the Jhikhu Khola watershed in Nepal. Nine years ago, a milk collection and chilling centre was established in the watershed and this provided the farmers with the incentive and opportunity to move into the market economy. Spoilage of milk was significantly reduced by the establishment of the chilling centre, and given the high demand for milk in Kathmandu, and the ease of transporting the milk to the capital city, many farmers have begun commercial milk production. There are both positive and negative short-term and long-term effects associated with this development. To assess them, we need to know how this change is influencing the number of animals, the demand for feed, the workload of women, the pressure on forests, and the crop production system. It appears that the water buffalo population has increased, but to date little attention has been paid to the implications for the sustainability of the labour, forest, and agricultural resources.

Farmers in the Jhikhu Khola watershed are poor, the land resources are under stress, and the question of how much the system can contribute to increasing milk production requires closer examination. Although livestock play a key role in farming systems in the middle mountains of Nepal by supplying the organic matter and nutrients that are critical for maintaining soil fertility, more livestock mean a higher fodder requirement, which might have a detrimental effect on the environment. From previous PRA surveys, it was evident that there is a great shortage of animal feed and that the workload of women is very high. Approximately 80 per cent of the work involved in livestock care is undertaken by women, who are responsible for collecting feed every day. The increasing emphasis on milk production will mean that more manure and animal power will be available, but at the same time feed demands will make the already critical feed supply situation worse and will add significantly to the workload for women.

The study described here was designed to determine the rate of change in milk production and to examine the possible impacts and consequences of a rapid increase in the number of buffalo and of the associated increase in demand for feed. The questions it was designed to answer included: 'How much can the cash flow from milk contribute to easing the feed shortages?' and 'Is it cost effective to use some of the grain produced to supplement animal nutrition?' Understanding the dynamics of the milk production system is a major undertaking because the changes are rapid, many different categories of farmers are involved as well as porters with different modes of transport, and there are large seasonal changes in the supply of and demand for both feed and milk.

Aims and Objectives

The goal of this study was to examine the positive and negative aspects of the increasing milk production in the Jhikhu Khola watershed, and to determine possible benefits and consequences for forestry and agriculture. The specific aims were to:

- determine the milk dynamics in the watershed with an emphasis on the rate of change of milk production and milk marketing over the past five years;
- document milk production and sources and supplies of feed;
- examine the income obtained from the milk trade, women's workload dynamics, feed demands from the forests, and feed use from arable lands; and
- evaluate farmers' perceptions regarding milk production, and identify the causes, coping strategies, and possible opportunities.

Methodology

Much of the information was gathered using Participatory Rural Appraisal (PRA) and Rapid Rural Appraisal (RRA) techniques to understand the trends, processes, and dynamics of milk production. Most of the information was georeferenced to facilitate the use of a geographical information system (GIS). GIS was used as the integration tool for all land use, forest, and agricultural resource information.

The survey was carried out during December 1998. It was conducted at three levels. First, semi-structured interviews were conducted with individual members of the cooperatives and the porters transporting milk at the Tamaghat Chilling Centre (TCC), which belongs to Nepal Dairy Corporation. Second, individual farmers were interviewed at five village cooperative collection centres. Third, information was gathered in 13 villages using participatory techniques from farmers involved in milk production, as individuals and in groups. Interviewees were selected at random. In all, 23 cooperative members and 16 porters from 39 different cooperatives in 15 different VDCs (including 10 cooperatives in 6 VDCs from outside the watershed) were interviewed at the TCC; 119 individual milk farmers were interviewed at five village cooperatives (29 in Shreerampati, Hokse VDC; 29 in Ranipani, Baluwa VDC; 26 in Kaphaledihi, Panchkhal VDC; 20 in Deourali, Rabi-opi VDC; and 15 in Upretithok, Koshi Dekha VDC—outside the watershed); and 71 farmers (six individuals and seven men/women groups) were interviewed in 13 villages in five VDCs (4 inside and 1 outside the watershed).

All data were incorporated into an Excel spreadsheet. The locations of individual farmers were marked both on aerial photos and on a 1:25,000 scale topographic map. The information was later incorporated into a GIS database.

Land use information from surveys performed in 1947 and 1981 (1:50,000 scale), and from aerial photo evaluations for 1972, 1990, and 1996 (1:25,000) were used to show the land use trends and to address the status and changes in the forests, shrubs, and grazing lands in the watershed .

The Chilling Centre

The first level of the survey was conducted at the TCC with different cooperative members and milk porters. The TCC was initially established at Lamidanda in 1978, but moved to Tamaghat in Panchkhal VDC of Kabhrepalanchok district in 1990. The TCC plays a key role in milk collection for Kathmandu. The total capacity of the centre of 12,000 litres of milk per day is fully utilised and it is planned to increase the capacity to 15,000 litres.

Figure 23: **Tanker Collecting Milk from the Tamaghat Chilling Centre**

The Cooperative Centres

The second level surveys were conducted at the cooperative centres. The village cooperative centres were established to collect milk from selected households in the villages. The cooperative committees consist of 9 members; a minimum of 25 households are needed to register with the district cooperative board. The TCC provides cane, chemicals, and the salary for the secretary of each cooperative. Transportation, rent, and other miscellaneous costs are covered by the individual cooperatives. The TCC receives milk from 40 cooperatives within the watershed and 23 outside, of which three are close by.

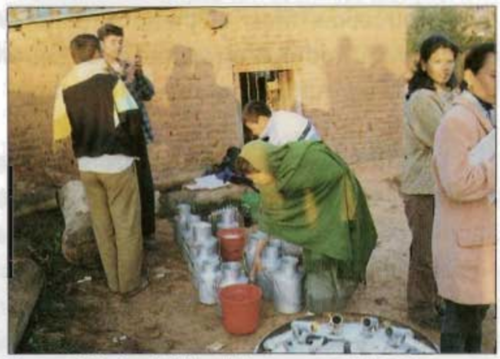

Figure 24: **Individual Farmers at the Cooperative Centre at Shreerampati**

Milk Farmers Group Survey (PRA)

The third level of the survey was conducted using participatory methods to obtain information on the geographical location, gender, ethnicity, trends, processes, and dynamics of milk production. Participatory Rural Appraisal (PRA) techniques were used to obtain a broad and rapid understanding of all aspects of the milk industry.

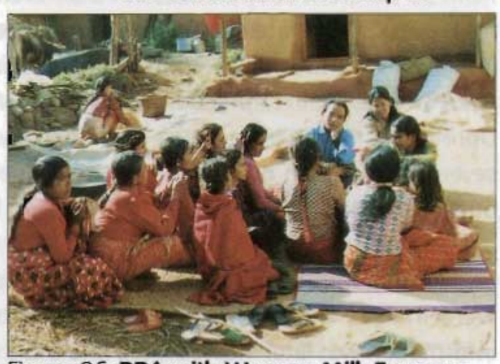

Figure 25: **PRA with Women Milk Farmers**

Results

Milk Dynamics in the Jhikhu Khola Watershed

There are two municipalities and twelve VDCs (Village Development Committee) in the Jhikhu Khola watershed (Figure 26). Sixty three cooperative centres bring milk to the TCC daily, 40 (63%) from within the watershed (Figure 26). The main cooperative centres within the watershed are in Anaikot, Baluwa, Hokse, Kharelthok, Maithinkot, Panchkhal, Patlekhet, and Sathighar VDCs; the main ones outside the watershed are in Jaisithok, Jyamdi, Kanpur, Koshidekha, Sangachok, and Sarshukharka VDCs. Two cooperatives from the adjoining district of Sindhuplachok in Sangachok and Pashupati VDC also bring milk to the TCC. There are some other milk cooperatives within the watershed (in Phoolbari, Kabhre, Rabi-opi, Devitar, and Patlekhet VDCs) that supply milk directly to Banepa.

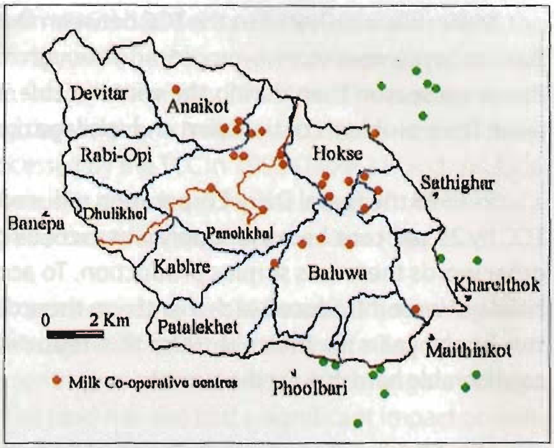

Figure 26: **Location of the Milk Cooperative Centres Whose Members were Interviewed at the TCC**

Data on the collection levels of milk from1994 to 1998 were obtained from the TCC. The results are shown in Table 21 and Figure 27.

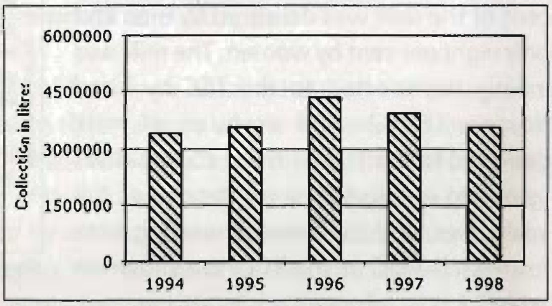

Figure 27: **Milk Collection at the Tamaghat Chilling Centre, 1994-98**

There was an increase of 26.5 per cent in milk collection from 1994 to 1996, followed by a decline of 18 per cent between 1996 and 1998. The decline at the TCC resulted partially when another chilling centre opened at Kunta, in Kabhrepalanchok District, and partly following the introduction in 1998 of 'milk holidays' (see below). Furthermore, many private dairies have been established in Kathmandu since 1996 and some farmers deliver to these directly. The decreasing trend is the result of competition from other dairy companies, not of a reduction in farm production of milk. Almost all of the farmers surveyed at the cooperatives indicated that their milk production during the last five years had increased substantially.

Table 21: **Milk Collection at the Tamaghat Chilling Centre from 1994 to 1998 (in lts)**

Month	1994	1995	1996	1997	1998	Total
January	267,324	369,851	411,448	485,913	337,000	1871,536
February	273,120	332,645	369,765	468,078	314,000	1,757,608
March	354,629	30,5711	359,059	444,277	285,000	1,748,676
April	344,652	26,4135	317,548	28,0,710	268,000	1,475,045
May	190,396	20,6613	244,478	309,961	224,000	1,175,448
June	167,257	178,696	227,653	261,947	219,000	1,054,553
July	174,628	203,900	228,497	303,074	294,245	1,204,344
August	312,329	232,413	303,628	177,000	263,462	1,288,832
September	285,019	303,952	41,1103	258,000	35,0191	1,608,265
October	379,547	359,769	479,429	277,000	26,7719	1,763,464
November	342,846	397,774	467,239	335,000	376,398	1,919,257
December	332,908	395,685	512,383	339,000	354,568	1,934,544
Total	3,424,655	3,551,144	4,332,229	3,939,960	3,553,583	18,801,572

Source: Chilling Centre, Tamaghat, 1998

More milk is delivered to the TCC between October and March (autumn-winter) than in April to September (spring-monsoon) although more milk is produced on-farm during the monsoon season than during the winter (Table 30). The lower deliveries in the monsoon result from problems of transport and spoilage during this season.

In 1998 the Nepal Dairy Corporation reduced the amount of milk they accepted at the TCC by 25 per cent because supply was exceeding the market capacity in Kathmandu—in other words there was surplus production. To accomplish this reduction, six to seven 'milk holidays' were introduced each month: on these days no milk was accepted at the TCC. After the boom years in the mid '90s, this reduction was a disappointment and created considerable hardship for the farmers.

The centre only accepts milk delivered from the cooperatives, not from individual farmers. The 39 cooperative representatives and porters interviewed at the TCC provided the following information. About 92 per cent of the milk was delivered by men and only eight per cent by women. The milk was mainly transported to the TCC by hired porters (60%). The amount of milk delivered to the TCC by these cooperatives (grouped within VDCs) on the day of the interviews, and the average walking time from each VDC to the TCC, are shown in Table 22.

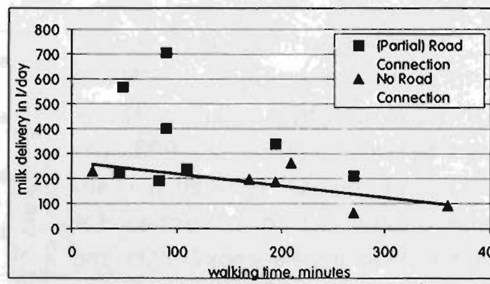

Figure 28: **Average Walking Time to the Chilling Centre versus Milk Delivered**

Table 22: **Milk Delivery to the TCC, Travel Distance, and Total Value**

S. No	VDC[1]	Milk Delivery Per Day (litres)	Walking Time (hours:mins)	Total End Sale Price of Milk (NRs)
1	Kanpur	60	4.30	1,242
2	Katunje	90	6.00	1,755
3	Kharelthok[2]	160	4.00	2,880
4	Koshi Dekha	184	3.15	3,312
5	Sathighar[2]	190	1.12	3,510
6	Sarsyukharka[2]	210	2.30	4,851
7	Sangachok[2]	240	1.50	5,040
8	Patalekhet5	400	1.30	7,800
9	Phoolbari	520	3.30	11,700
10	Hokse[2]	567	0.48	10,278
11	Maithinkot	580	2.50	11,286
12	Baluwa[2]	703	1.30	13,646
13	Anaikot[2]	1,130	0.45	21,387
14	Jyamdi[2]	1,355	3.15	26,333
15	Panchkhal	1,591	0.20	32,069
	Total /Average	7,980	2.34	157,088

Note: [1] Values refer to the sampled cooperatives from these VDCs (total 39) and are not necessarily the total values of VDC.
[2] Some VDCs are connected to the TCC by road (directly or partially) so that actual delivery time can be shorter.

The thirty-nine cooperatives (from fifteen VDCs) had delivered 7980 litres of milk to the TCC. Thus, among the sampled cooperatives, the average daily amount delivered in winter per cooperative on the days the TCC was open for collection was 205 litres. The average for all cooperatives over the whole year (including days when no milk was accepted) was 157 litres per day—estimated from the total milk processed by the TCC in 1998 (Table 21) and the total number of delivering cooperatives (63). There was a tendency for the villages from the VDCs closest to the TCC to deliver the most milk, and those furthest away the least (Figure 28).

The average walking time from the 39 cooperatives to the TCC was 2.3 hours/day, with a range from 12 minutes to six hours. The average walking time in different villages between the individual farms and the cooperative centres was 11 minutes, with a range of village averages from 5 to 21 minutes (Table 23). The road has also had a significant impact on milk transportation. Jyamdi VDC, the second largest milk producer, is about 3 hours 15 minutes walk from the TCC, but most of the milk is transported by truck along the highway.

Milk Production and Feed Requirements and Supplies

Data on milk production and supplies of feed were obtained during the survey of a sample of five village cooperative centres. In these villages all the farmers sold their milk through the village cooperatives. The sex of those delivering to the centres, the walking time, and the total number and average number of buffalo kept by those interviewed are shown in Table 23. Although women are responsible for most of the care-work related to the buffalo such as feeding, milking, grazing, and watering, the number of women milk farmers involved in actually selling the milk was very low. Ninety-five per cent of the deliveries to the village cooperative centres were made by men (Table 23). The average number of water buffaloes per household in the sample investigated was 1.44 (Table 23). The largest number of buffaloes per household was found in Deourali, which has direct road access, and the lowest number in Upretithok, located some five to six hours walking distance from the road. This indicates that market and road access play a significant role in milk production.

The total milk production per day in the sample of households interviewed at the village cooperatives, and the amount they sold through the cooperative to the TCC in the winter and

Table 23: **The Cooperative Survey - Gender Involvement, Walking Distance, Total and Average Numbers of Buffalo**

VDC	Village	People Interviewed Delivering Milk to the Cooperative			Average Walking Distance to Centre (min)	Total No. of Buffalo Kept by Those Interviewed	Average No. of Buffalo per Household Delivering Milk
		Men	Women	Total			
Baluwa	Ranipani	27	2	29	13	39	1.3
Hokse	Shreerampati	29	0	29	5	44	1.5
Koshidekha	Upretithok	11	4	15	21	15	1.0
Panchkhal	Kaphaledihi	26	0	26	5	36	1.4
Rabi-Opi	Deourali	20	0	20	13	40	2.0
Total/Average		113	6	119	11	174	1.44

Source: PARDYP milk survey, 1998

Table 24: **Daily Total Milk Production and Sales during Winter and Monsoon Seasons by the Sample of Milk Deliverers Interviewed at the Village Cooperatives**

Village	Milk Production l/day Winter		Milk Production l/day Monsoon		Milk Sales l/day Winter		Milk Sales l/day Monsoon		Average HH Consumption l/day	
	Total	Av per HH	Total	Av per HH	Total	Av per HH	Total	Av per HH	Winter	Mon-soon
Ranipani	188.5	6.5	235.0	8.1	139.5	4.8	181.0	6.2	1.7	1.9
Shreerampati	232.0	8.0	267.0	9.2	164.5	5.7	197.5	6.8	2.3	2.4
Upretithok	87.5	5.8	98.5	6.7	67.0	4.5	80.0	5.3	1.4	1.4
Kaphaledihi	161.0	6.2	186.5	7.2	110.8	4.3	130.0	5.0	1.9	2.2
Deourali	205.5	10.3	238.0	11.9	196.5	9.8	161.0	8.1	0.5	3.8
	874.5	7.4	1025.0	8.6	678.3	5.8	749.5	6.3	1.6	2.3

monsoon are shown in Table 24. The 119 households in the five cooperatives surveyed produced an average of 875 litres of milk per day in winter and 1025 litres per day in the monsoon, and sold 678 and 750 litres per day respectively. Milk production is about 15 per cent higher during the monsoon than in winter as a result of the availability of green grass during the summer, but the fat content is higher in winter. Although all cooperatives produced more milk during the monsoon one of the five, Deourali, actually sold less, and most kept slightly more for home use (including, for example, production of butter fat). This reflects seasonal problems with transport from areas located further from the TCCs as well as problems with spoilage during hot weather. In addition, farmers are not able to sell any of their supply on one day (or more) per week because of the recently introduced 25 per cent reduction 'milk holiday day' system.

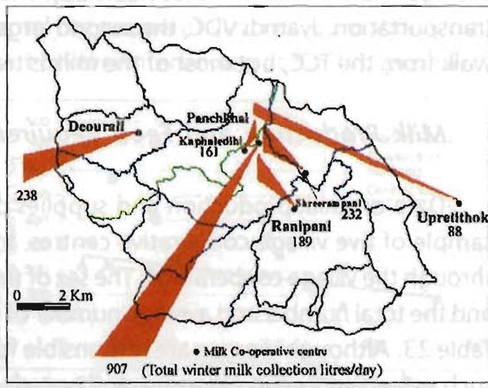

Figure 29: **Total Milk Collection from the Cooperative Centres**

Farmers were asked about the amount of feed given to the animals during the winter (November to February) and monsoon ('summer', mid June to September), and occurrences of feed shortage (Table 25). All the animals were stall-fed. Crop residues and grass were the two main sources of feed. The majority of winter feed (69%) derived from crop residues, the majority of summer feed from fresh grass. There was a shortage of crop residues from April to July in the spring and early monsoon, and of grass between October and May. Feed

Table 25: **Animal Feed Situation (winter/monsoon)**

Product	Winter (%)	Summer (%)	Total Shortages (months)
Crop residues	69	7	4
Concentrate feed	14	10	0
Grass	8	76	8
Forest products	6	6	10
Tree fodder	3	1	11
Total	100	100	

concentrate was the next most common source of feed but although available all the year round it is expensive and few farmers could afford it. Forest products comprised only six per cent of feed during both seasons, and were insufficient for most of the year. A similar study in the Bela-Bhimsensthan sub-watershed of Jhikhu Khola showed that between 1989 and 1994 it had become easier to obtain fodder from the forest (Shrestha and Brown 1995a).

Changes in milk production and the animal feed situation over the last five years were investigated during PRA surveys in thirteen selected villages. Grass collected from different sources played a very important part in the animal feed scenario. The data on grass collection for water buffaloes are summarised in Table 26. Women generally had sole responsibility for collecting grass from agricultural and forested land, although occasionally the whole family helped. Men more commonly collected fodder from fodder trees on private land, and were mainly responsible for the transportation of milk to the cooperative centres.

Although there were long periods of grass shortages and periods when very little feed of any type was available (Table 25), farmers have so far made no effort to store and preserve grass. The average time spent collecting grass and fodder is shown in Table 27. In winter little grass was available and the average household made only one trip per week to collect grass from rainfed agricultural areas. The average return trip took about seven hours. Tree fodder was collected from the farm once a week, taking another five hours. Most of the grass collected during the monsoon came from agricultural areas because forest access was restricted and the farmers had insufficient grazing land. During the monsoon an average household made 12 trips per week to collect grass from rainfed fields (equivalent to 22 hours/week) and 10 trips to collect grass from irrigated fields (30 hours/week). Further time was spent collecting grass from other sources.

Table 26: **Division of Labour for Feed Collection and Animal Care—Percentage Responsibility**

Product	Women Only	Men Only	Husband /Wife	All the Family	No Response	Total
Grass from irrigated land (*khet*)	77	0	0	8	15	100
Grass from rainfed land (*bari*)	85	0	0	15	0	100
Forest grass	69	8	8	8	7	100
Grass from grazing areas	15	8	8	0	69	100
Fodder from private fodder trees	0	47	15	0	38	100
Care of animals	38	8	54	0	0	100
Milk transport to cooperative collection centre	0	77	15	8	0	100

Table 27:.**Fodder Collection Frequency in the Winter and the Monsoon**

Product	Frequency (trips/week)		Time Spent (hrs/week)	
	Winter	Monsoon	Winter	Monsoon
Grass from irrigated land (*khet*)	NA	10	2	30
Grass from rainfed land (*bari*)	1	12	7	22
Forest grass	NA	NA	8	7
Grass from grazing areas	NA	NA	5	2
Fodder from private fodder trees	1	0	5	0
Total	>2	>22	27	61

The number of households in each village, the number involved in commercial milk production, and the main caste is shown in Table 28. In the thirteen villages in the study, 975 of the 693 households, or 71 per cent, sold milk. Brahmin families were the dominant force in commercial milk production. Tamang and Danuwar households kept less animals on average than did the Brahmins and far fewer participated in the milk trade. In Brahmin dominated villages almost all households were involved in commercial milk production. In contrast only 35 of the 120 households in Bakultar village in Baluwa VDC, which is dominated by Danuwar castes, sold milk and only six of the 105 households in Kalinjor village in Koshidekha VDC, which is dominated by Tamangs.

The Income from Milk, Women's Workload Dynamics, Feed Demand from the Forests, and the Use of Feed from Arable Lands

The price paid to the producers for milk is determined by the quantity and the fat content (Table 29). The average fat content of milk during winter was 6.5 per cent and in summer 5.8 per cent. The average price paid at the TCC over the year varied from Rs 2.50 to Rs 3.25 per one per cent fat content per litre. The fat content in water buffalo milk is much higher than that in cows' milk, which is one of the reasons why most of the milk in the study area comes from buffalo. Farmers normally keep cows' milk for home consumption.

Table 30 shows the estimated costs and benefits of milk production, assuming an average labour cost per day of Rs. 100 (the normal rate in the watershed for unskilled wage labour). The monthly value of milk and compost manure averaged Rs. 5364 of which Rs. 3348 was cash income. The total monthly expenditure averaged Rs. 5255 (including

Table 28: **Involvement in the Milk Trade**

VDC	Surveyed Village	Gender Group Interviewed	Number of HH Involved in PRA Sessions	Total No. of HH	Total No. of HH Selling Milk	Dominant Ethnic Caste
Hokse	Shreerampati a	Men	5	45	40	Brahmin
	Shreerampati b	Men	5	45	40	Brahmin
	Shreerampati c	Men	5	50	45	Brahmin
	Sub Total		_15_	_140_	_125_	
Pachkhal	Kaphaledihi	Men/ women	3	33	31	Brahmin
	Baniyadihi	Women	9	25	24	Brahmin
	Lamdihi	Men	1	100	100	Brahmin
	Sub Total		_13_	_158_	_155_	
Baluwa	Ranipani	Men/ women	4	75	50	Brahmin
	Bakultar	Men/ women	7	120	35	Danuwar
	Nayagaun	Men/ women	12	31	29	Brahmin
	Sub Total		_23_	_226_	_114_	
Rabi-Opi	Shikarkateri	Men/ women	8	30	30	Brahmin
	Deourali	Men	3	10	10	Brahmin
	Sub Total		_11_	_40_	_40_	
Koshidekha	Kalinjor	Men/ women	5	105	6	Tamang
	Salleni	Men/ women	4	11	8	Brahmin
	Sub Total		_9_	_115_	_14_	
	Total		71	975	693	

Table 29: **Average Fat Content in Milk from Different Villages in the Winter and Monsoon Seasons**

VDC	Village	Fat Content		Average price over the year per 1% fat content
		Winter %	Monsoon %	
Baluwa	Ranipani	6.6	6.6	3.00
Hokse	Shreerampati	6.2	5.8	3.00
Koshidekha	Upretithok	7.2	5.0	2.50
Panchkhal	Kaphaledihi	7.3	6.2	3.00
Rabi-Opi	Deourali	5.7	5.6	3.25
	Average	6.6	5.8	2.95

Table 30: **Monthly (Equivalent) Costs and Value of Benefits from Milk Production**

Animal Feed	Quantity	Total Value (Rs)
Dana (concentrate food)	50 kg	700
Dhuto (concentrate food)	60 kg	400
Maize flour	50 kg	500
Rice straw	8 bundles per day	480
Green grass (one *doko**/day)	30 doko* (900 kg)	150
Salt	15 mana*	25
Labour		3000
Total		5255
Mean monthly sales	180 litres/month	3348
Mean monthly home consumption	60 litres/month	1116
Compost manure (2 *doko** of compost/day)	60 *doko** (1800 kg)	900
Total		5364

Note: **doko*—standard basket; *mana*—volume measure, approximately 570 ml
The value of collected goods is based on the trade value if it were to be sold.

household labour). The average monthly net profit was thus about Rs. 109. If household labour costs are excluded, however, the net gain per month was about Rs. 3109, and if the potential trade value of collected fodder is also excluded then the actual benefit is even more. (These figures are only very rough estimates, however. They don't take into account the effect of milk holidays or other costs like the initial capital cost of a buffalo, the likelihood of death, costs of disease treatment, gain from selling calves, and downtime when no milk is produced.) This is a considerable amount of extra income for the average village resident.

The average time spent per day on activities related to milk production are shown in Table 31. Women were responsible for most of the activities, and spent more than twice as much time as men on buffalo management. Almost all farmers reported that their workload had increased substantially as a result of the new emphasis on the milk trade. According to the farmers, however, the income from one water buffalo was similar to that of a household member having a job in an office.

Table 31: **Average Time Spent on Activities for Milk Production by Men and Women**

Time	Men (hours/day)	Women (hours/day)
Morning	1.25	2.10
Day	0.40	1.30
Evening	0.35	1.10
Total	2.00	4.50

About 70 per cent of the farmers reported that the milk business had changed women's lives. Most of the money received was spent on household goods, and clothing and schooling of children. All farmers, male and female, wanted to increase milk production further.

The Farmers Perception of Problems in Milk Production, and Causes, Coping Strategies, and Possible Opportunities

The farmers purchased water buffaloes in order to make money by selling milk, but they felt they were not able to benefit sufficiently from this activity. They had great difficulty maintaining the buffaloes as they require special treatment and care throughout the day—the work required for one buffalo was considered equivalent to a full-time job in the city. Problems were identified at all levels—at the TCC, at the cooperative centres, and at the village level. These are summarised in the following sections.

At the Chilling Centre

- Problems

The major problems identified at the chilling centre are summarised in Table 32. The milk producers biggest concern was the 25 per cent reduction in the amount of milk accepted at the TCC, followed by transport problems, and the low prices paid for milk (Table 32).

Table 32: **Major Problems at the Chilling Centre**

Problem	Per cent
25% reduction in milk accepted at centre	36
Transportation	23
Low price of milk	15
Low pay for porters	13
Don't know	13
Total	100

At present the TCC accepts only 75 per cent of what the farmers are producing for sale. This new system is creating hardship for many farmers because the surplus exceeds home consumption needs and there are limited possibilities for processing the excess milk. On average the farmers produced eight litres of milk per day and consumed two litres at home (Table 33). The Nepal Dairy Development Company claims to have problems marketing the milk because of imports from India, and this has created this difficult spin-off situation for the farmers. These difficulties are the results of poor management and policies by central government (Thapa *et al*. 1997).

Table 33: **Daily Average Milk Production**

VDC	Village	Average Production/Day	Average Home Consumption/Day
Baluwa	Ranipani	6.5	1.69
Hokse	Shreerampati	8.0	2.33
Koshidekha	Upretithok	5.8	1.37
Panchkhal	Kaphaledihi	6.2	1.93
Rabi-Opi	Deourali	11.9	2.08
	Total Average	7.7	1.88

Source: PARDYP milk survey, 1998

The second biggest problem for the milk farmers was transportation. In most cases the milk had to be carried to the TCC. This could take several hours, and in the monsoon season when the temperatures are high spoilage of milk was also high. The physical effort of carrying the heavy cans was also significant. The third most important problem was the low price the farmers received for the milk (Rs18-22/l). Most farmers complained that the price of milk was lower than that of mineral water (Rs 19-20/l) or rakshi (local spirits, Rs.25-30/l).

- Causes

The farmers considered that the cause of their problems was the TCC policy of accepting 25 per cent less milk (86%), the policy of allowing milk imports into the country (7%), and the splitting of the cooperative centres (7%). Seventy five per cent of the farmers also commented that transportation was a major problem because of the lack of good tracks and roads to the TCC.

- Coping Strategies

As a result of the 25 per cent reduction in the amount of milk accepted by the TCC, 50 per cent of the farmers were forced to use more milk for home consumption than they could cope with. There were few other options for using the milk as there was a lack of fuelwood and water and the poor infrastructure is not conducive to taking the milk elsewhere for processing. Half of the farmers said that they didn't know how to cope with the milk surplus although some made *ghue* (butter fat).

- Opportunities

Fifty seven per cent of the farmers thought the surplus problem could be minimised if the management policy at the Dairy Company could be changed, seven per cent thought that better marketing might alleviate the milk surplus problem.

At the Cooperative Centres

- Problems

The major problems identified during the interviews at the village cooperative centres are shown in Table 34. Some were different to those identified at the TCC, although the problems were very similar for different groups and villages. Nearly one third of the farmers at the cooperative centres identified the shortage of fresh fodder during winter as the major problem.

Table 34: **Major Problems Identified by the Cooperatives Farmer Groups**

Major Problem	No. of Interviewees	%
Availability of grass	38	32
25% reduction in milk sales	29	24
Diseases	9	8
Availability of fodder	7	6
Lack of market	6	5
Water shortages	6	5
Concentrated feed	4	3
Roads	3	3
Other	7	6
Don't know	10	8
Total	119	100

Most of the farmers grew grass on their own agricultural land, since access to grass in the forest and on grazing land was restricted either by the state or by community user groups, but this grass was not sufficient to meet their needs. The second most important problem was the reduction in milk sales (24%), and the third diseases (8%).

- Causes

Twenty four per cent of the farmers said that the lack of grass was the result of water shortages. They were unable to grow grass because of the severe water shortage during the winter. About 16 per cent felt that it was more a case of a lack of land—which was sufficient for agriculture but not for grass production as well. Other causes identified for the shortage of fresh fodder were the limited access to grazing land (11%), population growth (11%), and forest closure (11%).

Forty one per cent of the farmers said that the reduction in the amount of milk accepted was the result of poor management and poor marketing by the Dairy Corporation.

- Coping strategies

Eighty seven per cent of the farmers said that they fed crop residues to the water buffalo during the winter to compensate for the lack of grass. The remainder said that they obtained some grass from the forest and rainfed areas, and grazed the animals on their own land.

- Opportunities

Fifty per cent of the farmers said that the existing shortage of grass could be solved by introducing improved grass seed, 19 per cent that it could be minimised by planting improved fodder trees, five per cent said that an improvement in the water supply would help, and 26 per cent offered no solution.

Conclusion

Milk production in the watershed expanded rapidly as a result of the establishment of the chilling centre. This resulted in the development of an extensive network of 63 collection centres from which milk is carried to the centre.

At present, the supply of milk in the watershed appears to be higher than the market capacity in Kathmandu, or at least the market capacity of the NDC. This has resulted in a 25 per cent reduction in the amount of milk accepted by the dairy corporation, which is causing confusion and hardship to the farmers. The increasing role of private dairies has still to be investigated. The real market potential and alternative possibilities for milk sales should be investigated, for example delivery to private dairy companies or production of alternative dairy products.

The farmers are eager to produce more milk, in spite of the fact that the majority said that milk production had added significantly to their workload. This is because of their need for cash income.

Milk production poses a particular problem for women, who reported that they spent an average of 4.5 hours per day over and above their previous workload on activities related to milk production. Men reported a two hours per day increase in their workload as a result of milk production.

Besides the market capacity in Kathmandu, the main constraints to milk production were the availability of green grass during winter, insufficient access to grazing lands and forests, and a significant shortage of water during winter. Feed concentrate was too expensive for most farmers, and the average land holdings were too small for additional production of grass.

Land use surveys of the Jhikhu Khola watershed have shown that between 1947 and 1996 there was a significant expansion of agricultural area at the expense of grazing land. At the same time forest degradation limited fodder supply, and access was reduced by the recent policy of turning national forests over to community management. Thus access to grazing areas has been reduced significantly, but the residues produced from the more intensive agriculture do not appear to be sufficient to compensate.

The milk marketing was mainly restricted to people of Brahmin caste and very few low caste people participated in the trade.

Since the excess milk can no longer be marketed and the farmers are apparently unable to consume all the excess, suggestions have been made that the milk be processed into other products. At present, this does not appear to be viable because of the lack of fuelwood, poor infrastructure, poor transportation network, and poor market access.

Notwithstanding the problems of overproduction, the heavy workload, and the modest returns in terms of cash income, almost all the farmers wanted to continue to keep water buffalo and even to produce more milk. Thus it is important to study fresh possibilities and opportunities, as well as methods to improve the quality of the grass and to introduce nitrogen-fixing grasses and fodder trees.

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Part TWO

The People and Their Forests

More People and More Forest: Population, Policy and Land Use Change in the Xizhuang Watershed

Xu Jianchu, Ai Xihui, Yang Yongping and Yang Lixin
Kunming Institute of Botany, the Chinese Academy of Sciences

Abstract

Land use changes in the Xizhuang watershed have been very dramatic over the past century, and historic events and national policies are considered to be responsible. Three periods of rapid forest degradation have been identified—World War II, the period of the 'Great Leap Forward', and the shift in the land use tenure system. Significant steps have been taken since these times to improve the forest resources, and the area under forest has expanded significantly as a result of two periods of aerial seeding of pine and the mobilisation and involvement of lowland farmers. There is no correlation between forest degradation and population growth. Forest expansion in recent years has come at the expense of farm land. Greater opportunities for off-farm employment resulting from more open policies are reducing the population pressure on the resources in the watershed. The strong enforcement of conservation policies, and responsible management of the forest by village leaders, is credited as the reason for the improvement in forest coverage.

Introduction

Baoshan was an important city more than a thousand years ago when it was situated on the South Silk Road, a major trading access route to South Asian countries. The local environment has been degraded throughout history because of the high population density and early development for intensive agriculture. Large-scale deforestation occurred during World War II during the frontier fighting against Japanese troops to the west of the Nujiang (Salween) river. Much timber was felled by Chinese troops for construction of bridges and houses, and for fuelwood. During recent decades, the local government has made great efforts to reforest the degraded areas using aerial seeding, transplantation, and natural regeneration through arrangements with social institutions.

Methodology

In 1997 and 1998 the PARDYP project developed an integrated spatial database for the Xizhuang watershed through the collection of secondary data, field surveys, interviews with farmers and other key informants, and an analysis of relevant socioeconomic policies. This database was used as a framework for analysing the changes in land cover and forest patterns over time, and as a tool for analysing the information collected through interviews and policy analysis.

The spatial database was developed using a 1982 topographical map as a base map, overlaying information from an existing 1991 land use map, and producing a 1998 land use map from field surveys. All the land-cover categories were digitised and entered into a geographic information system (GIS) using Arc/Info software at a PC workstation. The land cover was classified as forest, bush land, grassland, farm land, tea garden, settlement area, paddy, and other.

The socioeconomic database was developed through interviews with key informants including administrative and village leaders, older people who could provide general histories of land-use dynamics in the study area, and younger people who could provide insights into how land use may change in the future. Extensive household interviews were conducted with individual farmers in order to collect data on how families manage farm land across the landscape, and on how they collaborate with neighbouring farmers and communities when allocating and zoning land use. Participatory rural appraisal methods were used to construct time lines, and residents of the villages were interviewed to learn more about the socioeconomic factors contributing to their decisions to create or maintain forests in their area.

Topographic and land-use maps were used in the field as tools for soliciting discussion from local leaders and farmers on past land-use practices, present land-use conflicts, and their plans for the future. Secondary data on variables such as population and land tenure were collected from different government agencies at local administrative, township, and city levels. Government officials were interviewed in order to construct an account of both customary laws and government polices for governing the access to resources. The relations between government and local people under different land tenure systems were analysed to show how tenure affected the access of villagers to forest resources.

Results

The Xizhuang Watershed and Its History

The Xizhuang watershed is located 20 km north-west of Baoshan city near the highest peak in the Baoshan valley. It covers a total area of 3456 ha. As a result of population growth and urbanisation in Baoshan, the Xizhuang watershed is becoming increasingly important as a major source of water for irrigation, drinking, and industrial use. A drinking water company situated downstream of the Xizhuang watershed uses the stream as its principal source of water. One cement factory also relies on water from the watershed. Irrigation canals divert water for crucial irrigation activities in Banqiao Township, which lies in the main Baoshan valley. The Baimiao reservoir also has a water intake in the Xizhuang watershed. The water emanating from the Xizhuang is therefore of great importance to the area as a whole.

Administrative Structure

The Xizhuang watershed consists of two full administrative villages (Lijiashi and Qingshui) and one major natural village (Xizhuang).

The Historical Change in Environment and Society

A brief history of land and resource use in the watershed since 1950 is provided below.

- 1952, dense forest cover in the hills and shrubs along the river banks in the Xizhuang watershed
- Before 1953, practising of shifting cultivation (80% buckwheat and 20% potato) with 3-5 year fallow break, goats raised in the pasture land
- 1957-58, large areas of forest felled during the 'Great Leap Forward'
- 1958, construction of the Baimiao Reservoir downstream
- 1965, collectivisation of land and terrace construction
- 1966, pit-planting of some 1000 kg of pine seeds (*Pinus armandi)*
- 1967, pit-planting of another 1000 kg of pine seeds
- 1968, micro-hydropower station established
- 1974, forest survey in the watershed
- 1982, introduction of household responsibility system—more forest lost
- 1984, big floods in Qingshui village
- 1987, large-scale mud-flows and first aerial seeding of pine (*Pinus yunnanesis*)
- 1988, building of valley-side road for access to areas outside the watershed
- 1991, second aerial seeding
- 1994, 'wasteland auction'
- 1996, construction of new valley-bottom road

Different Stakeholders in Forest Resource Management

Because of the importance of the Xizhuang watershed, the local Baoshan municipal government and the local communities have made great efforts recently towards reforestation in the area. They have minimised logging operations in the state forest in the upper catchment areas, and restricted the cutting rate to 500 cu.m per year for fuelwood, the profits from which provide incomes for the 11 staff at the state forest farm. The Forestry Bureau arranged two aerial seeding efforts in the watershed in 1987 and 1991. In more recent years, the villagers in the lower areas of the watershed have been mobilised to plant trees at the beginning of the monsoon season. Both the administrative villages, but particularly Lijiashi, have strong traditional institutions that govern the access to forest resources in terms of collection of timber, fuelwood, and non-timber forest products.

The major stakeholders in the management and use of forest resources in the Xizhuang watershed are as follow:

- the State Forest Farm, established in 1960 with 11 staff;
- the Township Forest Station, established in 1982 with 14 staff;
- the forest guards, one in each village; and
- the villagers.

The Effect of Changes in State Policies on Land Tenure and Land Use

Since 1950 China has implemented numerous, and sometimes conflicting, policies affecting the ownership of agricultural and forested land. From 1983 to the present, Yunnan Province has implemented a policy called *'linyesanding'*. This policy defined and fixed the tenure and boundaries for three types of forest—state, collective, and household—with the objectives of stabilising the use of forest lands and partially shifting forest management control from the state to individuals. It was hoped that one of the results of this policy would be forest regeneration through community participation. The closed-canopy forests were commonly classified as state forest, while the local communities were given control of the collective, often degraded, forests for cutting timber for public and private use.

The major changes in land tenure policy in the Xizhuang watershed in the last fifty years are listed below.

- 1952, land reform
- 1958, the 'Great Leap Forward'
- 1965, people's commune
- 1982, household responsibility system
- 1994, 'wasteland auction'
- 1998, renewal of the household responsibility system for 30 years

Changes in Population Growth and Density

According to local key informants, the population in the watershed has doubled since 1950. The total population in Xizhuang is now about 4200 (1998). The population in Lijashi administrative village in the years 1983 to 1996 is shown in Table 35. The average annual population growth was close to two per cent. The population density in the Xizhuang watershed is about 122 persons per sq. km, which is quite high compared to other mountainous areas in Yunnan.

Table 35: **Population Growth in Lijiashi Administrative Village**

Year	Population	Year	Population	Year	Population
1983	1267	1989	1355	1995	1513
1984	1284	1990	1383	1996	1539
1985	1295	1991	1412	1997	not available
1986	1305	1992	1430	1998	not available
1987	1319	1993	1439		
1988	1326	1994	1451		

Changes in Land Use

Tables 36 and 37 show the area, and percentage change in area, of different types of land cover between 1982 and 1998.

The total area of forest increased significantly from 1112 ha in 1982 to 2346 ha in 1998. Most of the increase took place after 1991 and at the expense of grassland. Free grazing of

Table 36: **Land Use Changes over Time in the Xizhuang Watershed**			
Land Cover	Area in 1982 (ha)	Area in 1991 (ha)	Area in 1998 (ha)
Forest	1112	1370	2346
Bush land	157	35	269
Grassland	1015	1068	12
Farm land	902	531	471
Tea garden	145	185	206
Settlement	43	53	54
Paddy	81	68	0
Others	1	146	98

Table 37: **Percentage Change in Land Use between 1982 and 1998**			
Land Cover	Change 1982-1991 (%)	Change 1991-1998 (%)	Change 1982-1998 (%)
Forest	+ 23	+ 71	+ 110
Bush land	- 78	+ 669	+ 72
Grassland	+ 5	- 99	- 99
Farm land	- 41	- 11	- 48
Tea garden	+ 28	+ 11	+ 42
Settlement	+ 23	+ 1	+ 26
Paddy	- 16	- 100	- 100
Others	+ 146	- 33	+ 99

goats was one of the most important activities in the agroecosystem in the past, and even in the 1980s it provided the major source of cash income for local communities. Grazing of goats was totally stopped in the late 1980s through government enforcement and local institutions in order to conserve vegetation cover and the water sources in the Xizhuang watershed. After 1991, virtually all grassland was afforested. Heavy fines were imposed for illegal grazing and cutting of trees.

In the 1960s, rice was introduced and fields were converted into paddies. As a result of the high elevation, rice yields were very low. Most farmers stopped producing rice in the early 1990s, and in 1998 there were no paddy fields left. Paddies were converted into fields for rainfed maize and wheat since these products could easily be exchanged for rice grown more efficiently in the lowland areas around Baoshan.

The total amount of upland farm land also decreased significantly between 1982 and 1998 as a result of the expansion of both forested land and tea gardens. In 1996, Baoshan City started to cultivate tobacco in order to raise revenue for local government. Some of the most fertile agricultural lands in the Xizhuang watershed were converted into tobacco plantations with government technical assistance and subsidies, and according to assigned quotas for each village. However, the decreasing price of tobacco and the intensive labour requirement discouraged the local farmers, and as soon as the first crops of tobacco failed, buckwheat was introduced as a replacement.

Discussion and Conclusions

This study on land use change has provided a better understanding of the dynamics between people and resources.

The Effects of State Policies and Population Growth

Forest management has been much affected by state policies during the past four decades in China. Changes in land tenure and resource titles have much influenced local livelihoods and the behaviour of farmers in managing the natural resources. Forest degradation in Baoshan since 1940 can be attributed to three causes: the impact of World War II, the 'Great Leap Forward' movement, and changes in the land tenure system. The degradation during World War II mainly resulted from cutting of timber for the construction of bridges and houses. During the 'Great Leap Forward', a lot of forests were cut for the fuelwood that was needed for backyard steel furnaces. Later, during the Cultural Revolution, the lack of government authority made it impossible to control logging. During the collective period, state policies played a key role in the degradation of forests through poorly thought-out efforts to manage local economies. These policies failed to address the complexity of the numerous ecological and cultural niches that exist in the landscape. The shift in land tenure from the collective system to the household responsibility system in the early 1980s also resulted in significant destruction of the forest resources.

Although the population has increased significantly, there was no correlation between population growth and deforestation. In fact, the forest cover has increased significantly at the expense of farm land. The reason for this is the introduction of the open door policy that allows farmers to seek off-farm employment in urban areas. This development started in the 1980s and has flourished with market development and other employment opportunities, which have increased significantly in the past 10 years.

The Effect of Traditional Local Institutions

Traditional institutions play a key role in local resource management. These institutions have undergone many revisions (particularly in Lijiashi administrative village) in response to changes in the ecological and socioeconomic conditions in the watershed. National policy changes were strongly enforced by administrative village leaders in this area. They received several awards from Baoshan and Banqiao Township for their reforestation efforts and for improving the management of the forests.

The forest cover in Lijiashi administrative village has increased significantly compared to that in the neighbouring Qingshuo administrative village. Some farmers, however, complain that reforestation and stopping of grazing has greatly affected their cash income from livestock grazing, especially from goats which are now banned in the watershed.

Sustainable Management and Utilisation of Common Property Resources: A Case Study in the Bheta Gad-Garur Ganga Watershed in the Central Himalayas

Yeshpal S. Topal, Sanjeev K. Bhuchar, Pushpa Pant and Bhagwati P. Kothyari
G. B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora (UP), India

Abstract

In the mountain environment of the Indian central Himalayas, both ecological and socioeconomic sustainability is largely determined by the status of the common property resources (CPRs). Under the PARDYP project, an effort has been made to develop a better understanding of the sustainability of CPR through frequent interactions with village communities. The present paper describes some of the existing practices related to the use and management of CPRs in the Bheta Gad-Garur Ganga watershed, and discusses the factors behind both successes and failures in the management and utilisation of three main types of CPR–forest, pasture, and water. The main finding was that improved management and utilisation of CPRs is determined to a significant extent by the structure, composition, and degree of social cohesiveness of the user community. It is emphasised strongly that the CPRs in the Indian central Himalayan region can be the key to sustaining the rural hill economy. To exploit this potential, project teams need to act as facilitators rather than top-down 'doers'. Moreover, future research activities, development programmes, and community-selected interventions need to be undertaken using a participatory approach, with particular emphasis on ensuring the active involvement of women. This will ensure that the eco-cultural specificity of each region is recognised, and will provide a motivating force rather than an obstacle in the process of strengthening the sustainable management of CPRs.

Introduction

In the recent past, the mountains of the Indian central Himalayas have experienced extensive problems of environmental degradation as a result of commercial forestry, expansion of agricultural land, and demand for fuel (Jodha 1992), and this is leading to a process of degradation in both economic and social values. So far development in the Indian Himalayan region has been based on uncritical evaluation and extrapolation from western experiences of the economic growth model, and a gross disregard for the socio-cultural matrix of its traditional societies (Topal *et al.* 1998). This is particularly true with respect to the property rights of natural resources.

While the western approach recognises only two types of property rights, state and private, in India there are common rights as well. These rights are a bundle of entitlements defining both the rights and obligations in the use of common property resources and may include the right of access, the right to exclude other potential users, the right to manage, and the right to sell the resource base (Schlager and Ostrom 1992; Berkes *et al.* 1998).

Further to these, a number of Forest Acts and their amendments, from the Indian Forest Act of 1878 formulated during British India times to the Forest Conservation Act of 1980, have been passed by central as well as by state governments to ensure proper management and utilisation of forests.

The present study was undertaken in the hills of Uttar Pradesh and is based on micro-level evidence (the watershed and villages). Although the issues related to the CPRs are not new, it was only in the late 1960s, particularly after Garret Hardin's 1968 documentary 'Tragedy of the Commons', that proper attention was focused on this matter by academics and the scientific community. Since then, a number of reports have highlighted the importance and vital role played by CPRs in the economic activities of village communities, and particularly in the survival strategies of the poor (Jodha 1986; Wade 1987).

Formulations of conservation strategies and development programmes, and identification of potential alternative sources of income and livelihoods for the rural population of the Indian central Himalayan region, need to be based upon studies of the causes of imbalances in the ecosystem. The main finding in this paper is that better management and utilisation of CPRs is determined to a significant extent by the structure, composition, and degree of social cohesiveness of the user community. It is also argued that the management of such resources requires collective decision making, and the enforcement of rules agreed by group members. Hence, local social organisations and institutions are crucial (Berkes *et al.* 1998). The present study investigates some of the existing practices related to CPRs in the Bheta Gad-Garur Ganga watershed and discusses the factors behind both successes and failures in the management and use of the three main types of CPR—forest, pasture, and water.

The Study Area

The Bheta Gad-Garur Ganga watershed lies between 29° 50' and 29° 55' N and 79° 03' and 79° 30' E. The watershed is characterised by significant variations in terms of altitude (1090-2520 masl), slope, aspect, forest cover, soil characteristics, and hydrological features.

The watershed covers a total geographical area of 82.6 sq. km., and comprises 63 revenue villages with a total population of 14,524 (census 1991), mostly Hindus. Village communities are characterised by the existence of the traditional institution called '*zajmani pratha*', which is based on a give-and-take of different socioeconomic services. The economy is characterised by subsistence agricultural practices under both irrigated and rainfed conditions. All agricultural operations are still performed using age-old traditional implements and local breeds of bullocks. Adoption of science and technology in this sector can only be observed in terms of the use of chemical fertilisers and the recent introduction of a few improved varieties of crops.

Each household owns on average one bullock and one milch animal, and a few of them own sheep and goats. Buffaloes are mostly stall fed, with a few grazing openly in the nearby common areas—the pastures, forests, and wastelands.

Chir pine forest (*Pinus roxburghii*) is predominant in the watershed and occupies approximately 70 per cent of the total forest cover. The remaining forest is mostly of mixed type with a few patches of broad-leaved forest. The species of trees found include *Quercus leuchotrichophora* (banj), *Alnus nepalensis* (utis), *Grewia optiva* (bhimal), *Quercus glauca* (phalyant), *Bauhinia retusa* (kanol), *Bauhinia variegata* (kweral), *Ficus roxburghii* (timil), *Cedrus deodara* (deodar), *Myrica esculanta* (kafal), *Jhanjhari*, *Debregeasia longifolia* (tusar), *Celtis sp.* (khareek), *Prunus cerasoides* (padam), and *Rhododendron arboreum* (burans).

The village communities in the watershed consist mainly of three castes—Brahmins, Rajputs, and Scheduled Castes (SCs, formerly Harijans)—with a number of sub-castes, which are placed hierarchically in terms of social stratification. This type of mixed community is traditionally marked by the affectionate personal *zajmani* type of relations that sustain the socioeconomic life within the village. Most of the cultivable land in the villages is owned by the upper castes (Brahmins and Rajputs) with the SCs owning only small areas. Most of the SCs cultivate the fields of the upper castes on the basis of a customary food for grain share system called *baikar* in which approximately 1/10th of the total food grain produced during the crop season is provided to the SC farmer at the time of harvest. Lack of cultivable land among the SCs on the one hand, and demand for additional labour from the upper castes on the other, have forced the entire village community to develop this mutual interdependency. In addition, various sub-castes or functional groups within the SCs like Lohar (blacksmiths) and Dholi (drummers) provide their services to upper caste people as well as to their own community on various social, religious, and ritual occasions, receiving clothes, food grain, and money in return.

In the course of time some significant changes have been observed in *zajamani* relationships. For example, most of the SCs who provide their services to the upper caste during agricultural operations and on other occasions now prefer cash payment. Further, the Lohars prefer to sell their agricultural implements at the local markets instead of providing tools to the upper caste directly for food grain and clothes. The traditional *zajamani* relations based on exchange of goods and services are weakening day by day and being replaced by the more impersonal and dehumanised, but probably fairer, market economy.

The Survey

The survey was conducted at both the watershed and village level with the help of various secondary sources—for example the Almora District Census Hand Book, Census of India (1951-1991); the Almora District Statistical Hand Book, Office of the Block Development Officer, Garur; and information from the Office of the Tehsildar, Bageshwar and from local Land Revenue Records. The following criteria were adopted to select key villages.

- The **people**—e.g., social composition of the village community, population, and number of households

- The geophysical characteristics—e.g., altitude, geographical area, slope, aspect, and distance from the road head and Block Headquarters (BHQ)
- The economic status—e.g., per capita cultivable land, per capita livestock units, percentage of irrigated land
- The level of development—the degree of adoption of technological and development interventions by the village community, and the access to essential amenities and infrastructure

Data on the above attributes for all the villages of the watershed were analysed. They showed significant variations at village level. The 63 villages fell into ten different categories on the basis of the above attributes measured from least/lowest to most/highest. One village from each of the ten categories was selected for detailed study.

A detailed study of the population and basic community economics was carried out in all 622 households (HH) of these ten villages from January to September 1998. Quantitative data and other information were collected using a structured and pre-tested interview form, PRA techniques, participant and non-participant observation, special case studies, and informal individual and group discussions.

Results and Discussion

The social structure and composition of the village community varied from village to village. Most of the villages had three castes with seven to eight sub-castes, but some had only one caste. Some of the basic socioeconomic information for the ten villages is summarised in Table 38.

The sex ratio (female population per 1000 males) for the total sample population was 960, higher than for the UP hills overall (954), the state of UP (882), and the national level (929). However, it varied considerably from 742 (in Lohari Talli) to 1214 (in Bhitarkot). The literacy rate also varied from 61 per cent (in Laubanj) to 83 per cent (in Lohari Talli), with an overall average of 73 per cent.

The average HH size was 6.0 persons and the average proportion of main workers (engaged in economic activity for at least 183 days per year) 49.4 per cent. The average amount of cultivable land per capita was 0.14 ha, and the highest amount 0.27 ha (Doba Malla). The average number of livestock units per capita was 0.57, and the highest number 0.93 (Kafaldunga).

Agriculture is the main occupation in the watershed and was therefore placed first in the sustainability matrix. However, secondary data shows that between 1961 and1991 the percentage of main workers engaged in this activity decreased by 24 per cent in the Bheta Gad sub-watershed and increased by 1.3 per cent in the Garur Ganga sub-watershed. Since 1991, however, data for both the sub-watersheds suggest that overall the population engaged in agriculture as the main occupation has declined from 80 per cent (District Census

Table 38: **Basic Information from the Ten Selected Villages**

Features	Lbj	Kdr	Ptl	Dbm	Lht	Tkl	Btk	Bgl	Kfl	Bml	Total sample
Total no. of HHs	113	51	108	38	21	48	34	66	75	68	622
No. of Brahmin HHs	15	39	71	10	13	42	21	12	-	-	223
No. of Rajput HHs	71	-	1	22	-	6	13	54	10	-	177
No. of SC HHs	27	12	36	6	8	-	-	-	-	68	157
No. of other HHs	-	-	-	-	-	-	-	-	65	-	65
Total population	702	313	630	216	115	308	217	413	481	358	3753
Sex ratio	857	1006	994	1000	742	1139	1214	1005	795	1046	960
Average HH size	6.2	6.1	5.8	5.7	5.5	6.4	6.4	6.3	6.4	5.3	6.0
Literacy rate	60.8	72.6	79.5	78.0	83.0	80.7	73.6	79.9	63.7	75.5	72.8
Male literacy	62.4	85.7	92.9	95.4	96.7	85.4	83.1	90.1	74.7	91.9	82.5
Female literacy	58.9	60.3	66.9	60.9	64.4	76.8	62.3	69.9	49.4	59.3	62.9
Main workers* (%)	67.5	43.5	43.2	44.9	41.7	51.6	40.1	47.5	44.5	47.5	49.4
Per capita cultivable land (ha)	0.08	0.16	0.08	0.27	0.24	0.10	0.21	0.05	0.11	0.05	0.14
Per capita livestock (units)	0.51	0.33	0.52	0.71	0.72	0.76	0.36	0.47	0.93	0.37	0.57

Lbj = Laubanj; Kdr = Khaderiya; Ptl = Patali; Dbm = Doba malla; Lht = Lohari talli, Tkl = Thakala; Btk = Bhitarkot; Bgl = Bhagartola; Kfl = Kafaldunga; Bml = Bimola,

*those engaged in economic activity for the greater part of the year—at least 183 days

Source: Field investigations, 1998

Hand Book 1991) to 58 per cent (primary survey PARDYP 1998). Rapid population growth leading to out-migration from the watershed in search of more lucrative employment is the most important factor responsible for this; a contributory factor is the degradation and depletion of natural resources.

Forests, pasture, and water resources are the three major CPRs of immediate concern to the local people. Efforts were made to develop a better understanding of the relationship between communities and the CPRs through frequent discussion with the residents.

Degradation and depletion of CPRs in the Bheta Gad-Garur Ganga watershed has resulted from a number of causes. Over the last four decades (1951-1991) the watershed experienced a population growth of 44 per cent and the number of households increased by 35 per cent. This has placed increased pressure on various natural resources, and sustainable management and utilisation of the CPRs has become a major concern.

Major changes have also occurred in land cover and use in recent decades. Between 1963 and 1996, the total forest area decreased by 5.1 per cent and barren land was reduced by 2.3 per cent. This reduction was matched by an expansion of agricultural land, largely in the mid-elevation range between 1400 and 1600m. The area of CPR land and availability of water in each of the villages sampled is shown in Table 39.

Table 39: Status of the Main CPRs in the Sampled Villages

Village	*Panchayat Van*		Pasture (incl. wasteland) (ha)	Water Resources (drinking/irrigation)
	Area (ha)	Date established		
Laubanj	24.6	May 11, 1952	14.5	*Naula* x 4, tap x 6 Irrigation by Govt. canal
Khaderiya[1]	15.5	Feb. 20, 1970	5.3	*Naula* x 2, dhara x 3, tap x 10 No irrigation system
Patali	13.3	Feb. 28, 1956	2.0	*Naula* x 13, tap x 4 Irrigation by govt. canal
Doba Malla[2]			51.5	*Naula* x 3, tap x 2 Irrigation by a few personal water harvesting tanks
Lohari Talli[2]			0.9	*Naula* x 2, tap x 7 Irrigation by govt. canal
Thakala	30.6	Mar. 4, 1970	35.8	*Naula* x 4, tap x 10 (6 functioning, 4 out of action) Irrigation by govt. canal
Bhitarkote	14.1	Mar. 29, 1968	6.6	Tap x 7 Irrigation by govt. canal
Bhagartola	6.0	Apr. 20, 1971	6.3	*Naula* x 2, tap x 8 Irrigation by govt. canal
Kafaldunga	7.7	Dec. 15, 1956	6.0	*Naula* x 5, dhara x 1 Irrigation by traditional irrigation canals
Bimola[2]			6.2	*Dhara* x 1, tap x 5 Irrigation by govt. canal

Sources: Office of the Block Development Officer, Garur, and primary survey PARDYP 1998

Note: *naula*—an enclosure in which seepage ground water is tapped; *dhara*—a spring which flows openly

1 *panchayat* body non-existent at present

2 No *panchayat* forest

Panchayat van, or community forest, constitutes only about 6.9 per cent of the total forest area of the entire Indian Central Himalayas (GoUP 1995), but it is one of the most important CPRs for villagers and is a crucial resource for meeting the community's demand for fuel, fodder, and grass. In some cases village communities have developed and maintained their own rules, regulations, and policies for managing and harvesting their CPRs; other communities have not established rules and regulations with the result that the CPRs are in poor condition. Grass, leaf litter (mostly fallen pine needles), and fuelwood are the most important resources available from the *panchayat van*.

In most villages the *van panchayat,* a local governing institution, looks after all the matters related to the community forest. The *van panchayat* is an elected body and has a fixed tenure of five years. The body is headed by a '*surpanch*' and the number of members may vary from five to eleven (for more details see the *Panchayat Van Niyamawali, GoUP 1976*). The *van panchayat* has legal powers to develop its own rules and regulations for sharing the costs and benefits from the community area. The powers and limitations of the *van panchayat* are clearly listed in the *Panchayat Van Niyamawali 1976* under section 28 (2) of the Indian Forest Act, 1927. Fifty to 70 per cent of the total area of *panchayat van* forest is kept closed to open grazing and grass collection throughout the year, except during one month in October/November when it is usually opened for grass collection only. The *panchayat van* is divided into a number of plots depending upon the number of households within the village. The right to collect green grass from the plots is distributed by a lottery method. The number of a particular plot and its cost are written on a slip of paper, one representative from each village household selects a slip from the bag and is then entitled to cut the grass from the plot named on the slip after paying the cost to the *van panchayat* body. The cost of a plot may vary from Rs.10 to Rs.80 depending upon its size and productivity. Sometimes the slip may be sold to another household if the 'winner' does not, for example, either need the grass or have the labour to cut it.

The HHs also share the leaf litter from their *panchayat van*, but the system of sharing is different. During the months of May, June, and July, each village HH is charged an equal amount (usually Rs.5 or Rs.10) for the collection of pine needles from the *panchayat van*. Only one member from a HH is permitted to collect pine needles at any one time, even though the quantity collected depends upon the size, effort, and strength of the selected individual. Pine needles are used in two ways: first as a bedding material for cattle; and second, after mixing with cattle urine and dung, as compost on fields (Laubanj, Kafaldunga, Patali, and Thakala).

Villagers are also entitled to obtain timber and stones or slates for housing repair and construction purposes from the community areas, and these are made available at very low cost. Trees marked silviculturally appropriate for felling, or having fallen naturally, are sold through auction to the local community—the cost usually varies from Rs.20 to Rs.80. *Van panchayat* bodies maintain the right to charge penalties when rules are broken, for example when someone is found guilty of illegal tree felling in the community area. However, the *van panchayat* is only permitted to charge a penalty of up to Rs.500; if the amount should exceed this, the local Divisional Forest Officer (DFO) is responsible for the matter. A few cases of penalty charging by the *van panchayats* were recorded in the study watershed.

The rules on benefits and cost sharing of CPRs provide two main benefits to village communities, first they prevent conflicts and disputes among the villagers, and second they provide revenue, which is used to purchase community assets like cooking ware, *panchayati* beds, and carpets. The maintenance cost and salary of the watchman of the *van panchayat* area is drawn from the same revenue (Laubanj and Kafaldunga).

Water for both irrigation and drinking is another crucial CPR on which village communities rely. Until 1917, there were no acts or legal rules concerning water resources in the study area, and the water resources were used on the basis of '*pahala huq*' (prior right). In 1917, the 'Kumaon Water Rules 1917' were enforced by declaring all water resources to be the property of the state government. The currently relevant act on the use of the water resources in the study area, the 'Kumaon and Garhwal Jal Sangrah, Sanchay, and Vitaran Act, 1975', was passed by the state legislative assembly through the then Minister for Community Development and Panchayati Raj, Mr. Baldev Singh Arya.

After the 1950s, the state government started to develop irrigation canals. Previously all irrigation systems had been managed by the village community or *panchayat*. In some cases, the water resources were so small that a special association (*pani panchayat*) was needed to enable the beneficiaries to manage the system themselves (Shah 1992). Although this type of local *pani panchayat* was quite common until the late forties, it has become very rare now. These days most irrigation systems are the property of the state government, and the farmers pay for use of the scheme and the water.

In villages where no formal irrigation system has been developed by the state government, people maintain their own systems, locally called '*sanjayati gool*'. In such cases, the distribution of water for irrigation depends on mutual understanding between the villagers. The proper functioning and maintenance of the system is the common responsibility of each household.

Field verification showed that the area identified by the local land revenue department as pasture' lies on moderately to highly degraded land. Furthermore, it was very difficult to observe any clear-cut differences between pasture and wasteland. In all cases, areas classified by the local authorities as pasture or wasteland are open for grazing throughout the year and no revenue is charged for using this resource.

Table 40 shows the mode of cost and benefit sharing in the different villages. Sharing was more equal in villages with a more complex structure and more social heterogeneity.

Table 40: **Composition of Village Communities and Mode of Sharing Resources**

Village	No. of Castes	No. of Sub-castes	Types of Benefit	Mode of Sharing Costs	Mode of Sharing Benefits
Laubanj	3: Brahmins, Rajputs & SC	Purohit (B), Pant (B), Mishra (B), Pandey (B), Koranga (R), , Garhiya (R), Alamiyan (R), Harijans (S)	Green grass Fuelwood Pine needles Grazing	Equal Nil Equal Nil	Equal Unequal Equal Equal
Khaderiya	2: Brahmins & SC	Joshi (B), Pandey (B), Harijans (S)	Open grazing Fuelwood Pine needles	Nil Nil Nil	Unequal Unequal Unequal
Patali	3: Brahmins, Rajputs & SC	Joshi (B), Pandey (B), Bhatt (B), Pathak (B), Adhikari (R), Harijans (S),	Green grass Fuelwood Pine needles Grazing	Equal Nil Nil Nil	Equal Unequal Unequal Equal
Doba malla	3: Brahmins, Rajputs & SC	Upreti (B), Joshi (B), Mehra (R), Bora (R), Harijans (S)	Open grazing Fuelwood Pine needles	Nil Nil Nil	Equal Unequal Equal
Lohari Talli	3: Brahmins, Rajputs & SC	Pandey (B), Joshi (B), Lohani (B), Harijans (S)	Open grazing	Nil	Unequal
Thakala	2: Brahmins & Rajputs	Pathak (B), Tewari (B), Kulegi (R)	Green grass Pine needles Fuelwood	Unequal Nil Nil	Equal Unequal Unequal
Bhitarkot	2: Brahmins & Rajputs	Kandpal (B), Sati (B), Dasila (R)	Open grazing Fuelwood Pine needles	Nil Nil Nil	Unequal Unequal Unequal
Bhagartola	2: Brahmins & Rajputs	Baiswal (B), Bora (R), Bisht (R)	Open grazing Fuel wood	Nil Nil	Unequal Unequal
Kafaldunga	2: Rajputs & OBCs	Rawat (R), Negi (R), Bora (R), Nath (O), Giri (O), Puri, (O)	Green grasses Fuel wood Pine needles Grazing	Equal Nil Equal Nil	Equal Unequal Equal Equal
Bimola	1: SC	Harijans (S)	Open grazing	Nil	Equal

B = Brahmins; R = Rajputs; SC = Scheduled Castes; O = Other Backward Castes
Source: field investigations, PARDYP 1998

Conflicts and Options between Multiple Stakeholders

Case Study No. 1

The boundaries of the Bhitarkot *panchayat van* adjoin Kafaldunga village, which is far from and out of sight of Bhitarkot village. As a result, illegal encroachment of Bhitarkot's *panchayat van* area by the villagers of Kafaldunga has been a conflict issue between these villages for a long time. The products of this *panchayat van* (e.g., grass, fuelwood, pine needles) are being illegally shared by the other village (Kafaldunga), and this conflict is identified by the Bhitarkot villagers as an important obstacle to managing the *panchayat van* effectively. When the issue was raised during a number of informal meetings held between the Bhitarkot *Van Panchayat* and the PARDYP-India team, as well as during the PRA exercise, it was decided to learn from and imitate the practices of villages like Lawbanj and Thakala where management systems were working well. The Bhitarkot *Van Panchayat* has agreed to pass similar resolutions for their own village, and the appointment of a *'chowkidar'* (guard) by the villagers was also seen as an appropriate solution to their problem.

Case Study No. 2

Illegal encroachment and acquisition of land belonging to the Bhagartola *Panchayat Van* by individual HHs has created major management problems for the Bhagartola *Van Panchayat*. This has been exacerbated by doubtful and improper demarcation of the land by government officials. During meetings and informal discussions between the *Van Panchayat* and the PARDYP-India team, it was decided that the first step to solving this intra-village conflict was to clearly demarcate the boundaries both in the field and on maps, and that this should be done by the local revenue officials.

Case Study No. 3

There are a few historical and important cases within the watershed which show that the interventions undertaken by the people themselves can be more effective and fruitful than those imposed by state officials. The following case is an example.

Until the late 1960s, the cluster of villages that included Naugaon village had no irrigation system and suffered from severe irrigation and drinking water supply problems. Mr Udai Ram of Naugaon village, a member of the SCs, raised this issue on several occasions with the government department concerned with no result. He finally took a personal initiative and started to construct a small earthen irrigation canal (*gool*) starting from the higher point of the Garur Ganga stream and passing through Thakala village. A number of local people reported that Udai Ram spent about Rs.20,000 of his own money and that the higher caste people of Thakala and the other villages did not provide him with any cooperation, financial help, or assistance with labour. When the *gool* became functional it attracted the attention of the state government and was taken over by the irrigation department who then became responsible for management and maintenance. Udai Ram was offered the post of *chowkidar* (guard) by the then District Magistrate but refused because:

- he was of the opinion that the water from the *gool* should not be shared by the higher caste people, since their souls could be polluted by using the water touched by an SC person; and
- the higher caste people had no moral right to the water because none of them had helped or cooperated during the construction.

Mr. Udai Ram was finally honoured in public and the District Magistrate placed a garland around his neck. Now the *Koltulyari Nahar,* the name given to the *gool,* is one of the major irrigation canals in the watershed and an important CPR for a number of villages. Unfortunately all the water carried by this canal is being used by other villages adjacent to its course and the villagers of Naugaon still suffer from a severe shortage of water for irrigation.

General Comments

Socioeconomic aspects and indicators are relevant for better understanding of the sustainable management and use of CPRs, and the causes of degradation and its prevention. At the same time, socioeconomic studies also help to target areas where management improvements can potentially result in higher productivity and returns from the CPRs.

Since time immemorial, the CPRs in the Indian central Himalayas have been managed by the traditional *'padhanchari'* system, in which the *padhan* (village head) together with the *panchayat* body was responsible for all the CPRs. The office of the *padhan* was hereditary, and thus there were many possibilities for the incumbent to exploit the weaker sections of the village community. These problems were tackled by the *panchayati raj* system and the subsequent formation of formal local institutions like the *village panchayat* and the *van panchayat*.

The results of the present study indicate that social heterogeneity within a village leads to greater efficiency in the management and harvesting of CPRs. Table 3 shows that the cost and benefit sharing is slightly more equal in villages with a complex structure and a more heterogeneous social composition in terms of sub-castes (e.g., Laubanj, Kafaldunga, Patali, and Doba Malla) than in villages with a simpler structure and less heterogeneity (e.g., Khaderiya, Lohari Talli, Bimola, Bhagartola, and Thakala).

Discussions with people from different sub-castes within the more heterogeneous villages revealed that they are compelled by their social and economic interests to see that rules are established to ensure equal distribution of the benefits from the CPRs to all community households. The least heterogeneous villages have failed to develop and enforce such fair-share rules. In such villages, families are often related and relationships are closer, and thus the enforcement of rigid rules and penalties against those breaking rules is less easy.

Gender issues are also crucial in the management and harvesting of CPRs. While conducting PRA exercises in a few of the villages, it was found that the women in the watershed have a better knowledge of the relative importance of different fodder, grass, and fuelwood species than the men. Women have also been reported to be better environmentalists than men (Gbadegesin 1996). Usually, females in the Indian central Himalayas become very familiar with the forests and pastures from the age of six to seven. Almost all the activities related to forests, grass, and agriculture are performed by women, but their participation in local institutions is almost negligible. Age-old traditions dictate that women should not take an active part in decision making either inside or outside the house.

Conclusion

The significance of CPRs is that the established governance groups represent locally-devised mechanisms to address problems of resource use, allocation, and conflict (Berkes *et al.* 1998). In the Indian context, CPR local management groups and institutions are essential for two reasons.

- The nation is set on a path of decentralisation, and the process can only be moved forward by giving decision-making authority to the grass roots level.
- It is believed that local people are, or can be, the best managers of their common resources.

In some villages, people have developed their own rules and regulations for managing and harvesting their CPRs to meet their day-to-day basic demands for fuel, fodder, and grass, while keeping the idea of sustainability in mind. The entire village community follows these rules strictly and when any deviation is observed the local institution uses its power to discipline the miscreant or improve a difficult situation.

It is emphasised strongly that the CPRs in the Indian central Himalayan region have the potential to be the key for sustaining the rural hill economy. In this connection, future research activities, development programmes, and community interventions need to be based on a participatory approach and to ensure the active involvement of women.

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Rehabilitation and Community Forestry in the Xizhuang Watershed

Yang Lixin, Xu Jianchu, Yang Yongping and Chen Deai
Kunming Institute of Botany, Chinese Academy of Sciences

Abstract

A series of forest activities have been carried out in the Xizhuang watershed as part of the People and Resource Dynamics Project (PARDYP) in mountain watersheds of the Hindu Kush-Himalayas. Three nurseries were established to provide (tree) seedlings, legumes, and new varieties of tea bushes, and the local capacity to promote afforestation was enhanced. Several PRA tools such as matrix scoring and ranking were used to facilitate species selection by the farmers, and to document decision making in forest resources management. During the two years of project implementation, farmers selected and planted thousands of timber species (Pinus armandi), nitrogen-fixing legumes, fruit trees (pear and walnut), and bamboo plants for gully erosion control. Two degraded forests in the watershed were selected for rehabilitation research. A range of species has been planted to control soil erosion and improve soil fertility. Efforts are being made to improve the technical training, local capacity, and organisation of community forestry groups. This training is crucial for sustainable forestry development in this watershed.

Introduction

The Xizhuang basin, a typical watershed, lies between 99°06′ and 99°13′ E and 25°13′ and 25°17′ N in the mid-mountain region of western Yunnan near Baoshan City. As a result of heavy long-term human exploitation of the natural resources, degradation is widespread and enormous efforts are needed to arrive at a sustainable use of the natural resources. The watershed was selected as a study site in 1996. The aims of the research in the area are to understand the causes and extent of environmental degradation, to identify the constraints, to seek practical solutions for management problems, and to involve the community in the research. Forest resources are critical in the daily life of the local people and form an integral part of the agricultural system. In a watershed context, forests are linked to water and soils, and in order to improve the resources an integrated management approach is needed. This requires a long-term view and stakeholder involvement from the beginning. A series of forestry activities have been carried out during the past three years. These include baseline surveys, establishment of nurseries, and reforestation of degraded sites. The project is still in the early stages, thus only the first findings of these research initiatives are presented.

The Forest Resources in the Watershed

The Xizhuang watershed is located in the southern section of the Hengduan Mountains. Influenced by the regional geological history and active tectonic movement, the landforms are complex and diverse. Air currents from both the south-western Indian Ocean and the south-eastern Pacific Ocean influence the climate in the watershed. The annual climatic cycle is dominated by distinct wet and dry seasons. Red soils dominate. They originate from many metamorphic parent rocks (slate, gneiss, phyllite) and from igneous granitic rocks.

The original natural vegetation consisted of a semi-moist broadleaved forest, but much of this disappeared many years ago. As one of the older cities in China, Baoshan has a very long history of human activity that can be traced back to the Neolithic Age. The Yuan Dynasty period (1279-1368) was especially active, a time when a great number of inland people migrated from eastern China to Baoshan. Most of the natural forests were destroyed through shifting cultivation, the traditional practice, and then replaced by dry-tolerant, secondary pine forests. Three distinct major deforestation events in the current century were identified through field surveys and interviews. In the 1920s and 1930s, when the population in the watershed was still small, shifting cultivation, the introduction of intensive plantations of opium and buckwheat, and overgrazing, caused a rapid decline in forest cover. At the end of the 1950s, large areas of forest were felled to provide firewood to fuel iron and steel factories during the 'Great Leap Forward'. At the beginning of the 1980s, forest resource use and management rights were allocated to individual households, which in many cases resulted in an unexpected over-harvesting of forest resources.

Most of the pine forests in the Xizhuang watershed were planted between the 1970s and the present using pit-planting or aerial seeding methods. The forest coverage has clearly increased over the past 10 years, particularly in Lijiasi and Qingshui villages (Xu *et al.* these proceedings). This is the result of a significant improvement in the community's awareness of the benefits of afforestation, and of the enforcement of forest protection by local institutions. Updated statistics have been compiled on the distribution of tree species, genera, and families in the watershed on the basis of a recent inventory.

Local residents are generally very knowledgeable about the use and management of forest resources, and the importance of forests as a source of construction materials and firewood for household use. Local people also collect many kinds of non-timber forest products such as mushrooms, fodder, and forest litter for composting. Some patches of forest land are also used for grazing. Many people realise that forests play an active role in influencing microclimatic conditions and controlling environmental hazards.

There are many different users and owners of the forest resources. In the high-mountain area of the watershed the forests are state-owned; in the central section of the watershed most of the forests are collectively-owned or household-owned; and in the downstream area and lowlands most forest land has been transformed into farm land to meet rapid demands for crop production, and is thus registered to households. Some steep slopes have been entirely degraded as a result of deforestation or cultivation.

Although forest coverage in the Xizhuang watershed is clearly on the increase, there are still many problems and constraints that affect the sustainable use of the forest (see Yang, Wilkes, and Xu these proceedings). For example, the large-scale monoculture of several pine species (e.g., *Pinus yunnanensis, Pinus armandi,* and *Pinus kesiya var. langibianensis*) has led to a decline in biodversity, and restricts the multiple use of forest resources. External technical support is needed for community forest management for establishing nurseries, plantations, pest and disease control, forest development and planning, and forest monitoring. In some degraded areas, the recovery and growth of native plant species is very difficult or even impossible because of habitat deterioration, and it is a challenge to plan and design reforestation activities, including the introduction of exotic plant species. Significant issues that need to be addressed are how to motivate local participation in community-based forest management, and how to build capacity within the local institutions.

PARDYP Forestry Activities and Achievements

Establishment of Nurseries

In previous tree-planting projects most seedlings were provided by state-owned forestry nurseries. The survival rates in the new plantations were very low as a result of the poor quality of the seedlings after long-distance transport, and the lack of community participation in the programme. The establishment of community-based nurseries should decrease the expense of seedling production, and help sustain local forest plantations better. For this reason, PARDYP paid special attention to building community nurseries within the watershed. Three nurseries were established to provide timber seedlings, legumes, and new varieties of tea. During the first two years of the project, more than 70,000 plants of *Pinus armandii* and nitrogen-fixing leguminous plants were distributed to villagers for the establishment of plantations, and nearly 40,000 quality tea seedlings will be distributed in 1999.

Rehabilitation

In the first phase of PARDYP, two sites in the Xizhuang watershed were selected as rehabilitation sites. One is located in the downstream section of the Xizhuang River near Tiger Cave, at an elevation of 1820-1860 masl. As a result of the steep slopes and heavy soil erosion in the past years, the topsoil is very thin, lacks soil nutrients, and has low productivity. The existing plants grow very slowly and natural plant regeneration has been poor. A series of different combinations of plant species, cropping patterns, and land preparation techniques were used to rehabilitate the area (see Figure 30 and Table 41).

The second rehabilitation site is in Ganwangkeng near Qingshui village. A major landslide generated extensive soil erosion problems which are threatening the nearby farm land and settlement. Some nitrogen-fixing plant species (of the types shown in Table 41) have been cultivated on this site to improve the soil fertility.

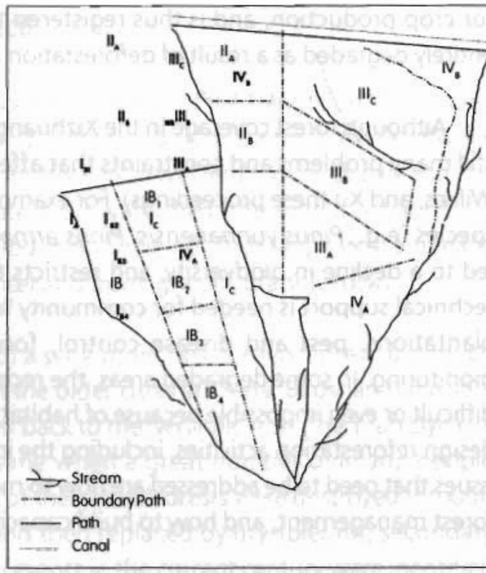

Figure 30: **Sketch Map of Plan for Rehabilitation at the Tiger Cave Site**

Agroforestry

Agroforestry techniques have been identified as useful for improving biomass production and stabilising the soils in the farming systems in mountainous regions. These techniques help protect the environment and meet the multiple local resource needs. Field surveys showed that the local people are enthusiastic about planting fruit trees as a part of the existing farming system. A matrix scoring of preference was carried out in the watershed, the results are shown in Table 42. The villagers chose pear and walnut as their preferred species for planting. So far, 1,700 pear tree seedlings and 1,300 walnut tree seedlings have been cultivated in Qingshui and Xizhuang. These trees are inter-cropped with wheat or maize on cultivated farm land. A further 2,050 seedlings of Japanese sweet persimmon were planted in the watershed this year.

Table 41: **The Reforestation Design for the Tiger Cave Rehabilitation Site**

Plot			Land preparation	Tree species	Cropping Pattern
I	IA		Pit-digging	*Leucaena leucocephala*	Plot
	IB	IB1	Contour	*Tephrosia candada*	Plot
		IB2	Contour	*Leucaena leucocephala*	Plot
		IB3	Contour	*Acacia yunanensis*	Plot
		IB4	Contour	*Acacia mearnsii*	Plot
	IC		Pit-digging	*Acacia mearnsii*	Plot
II	IIA		Pit-digging	*Tephrosia candada,* *Acacia richii*	Plot
	IIB		Pit-digging	*Acacia richii*	Plot
III	IIIA		Contour	*Acacia mearnsii,* *Acacia yunnanensis* *Leucaena leucocephala*	Line
	IIIB		Contour	*Acacia mearnsii* *Leucaena leucocephala* *Tephrosia candada* *Acacia yunnanensis,*	Line
	IIIC		Contour	*Acacia mearnsii* *Leucaena leucocephala* *Acacia yunnanensis* *Tephrosia candada*	Line
IV	IVA		Pit-digging	*Leucaena leucocephala*	Plot
	IVB		Pit-digging	*Acacia mearnsii*	Plot

Table 42: **Matrix Scoring of Tree Species in Zhangjia Village**

Criteria	Walnut	Chest-nut	Pear	Small Apple	Crab-apple	Peach	Sichuan Pepper	Persi-mmon	Apple
Survival rate	7	3	8	8	9	10	5	8	8
Seedling survival	7	5	8	8	10	10	10	6	8
Seed collection	7	6	6	6	10	10	9	7	6
Management	8	6	8	7	10	7	6	7	7
Storage of fruit	10	10	6	6	6	5	8	7	6
Transportation of fruit	10	10	6	6	7	5	9	7	6
Market accessibility	10	10	6	9	4	7	9	9	8
Maturation time	5	7	7	8	10	10	8	6	8
Productivity	5	2	6	8	10	8	5	6	7
Growth rate	8	7	8	8	9	10	7	8	8
Price	10	10	7	7	3	9	8	6	8
Plantation history	8	7	10	10	8	10	8	10	7
Method of grafting	8	6	10	9	9	10		8	9
Soil fertility improvement	10	7	7	7	7	7		9	7
Avail. of wild germplasm	+	-	-	-	+	+	-	-	-

Notes: score 1= the lowest preference, 10= the highest preference.

Bamboo Plantation

Bamboo is a typical plant in the watershed and has multiple uses including construction, farm tools, furniture, and food (young shoots). Bamboo plantations are also good for controlling landslides and soil erosion. In 1998, 895 *rhizobium* clumps and stem sections of bamboo were cultivated along water channels in the watershed (245 in Lijiasi, 505 in Qingshui, and 150 in Xizhuang).

Sloping Agricultural Land Technology (SALT)

SALT is now widely used in the Hindu Kush-Himalayan region as an effective way of bioterracing the landscape to prevent soil erosion and improve soil nutrients. As a trial, 32 *mu* (2.13 ha) of farm land opposite Tiger Cave in Xizhuang village have been planted with some nitrogen-fixing leguminous species. However, as a result of local intensification of land use, it will require some time for the farmers to accept SALT.

Training

During the implementation of PARDYP, a three-day training workshop on forest management was held within the watershed. Foresters and technicians from the Forest Departments of Baoshan City and Kunming instructed local farmers in practical knowledge and techniques for nursery establishment and forest management such as seedbed preparation, pest and disease control, grafting, and thinning. In the future, such workshops will be carried out more frequently and involve a larger audience. The criteria used to select tree species for afforestation are shown in Table 43.

Table 43: **Ranking of the Importance of Timber Tree Species**

Criteria	*Pinus yunnanensis*	*Pinus armandi*	*Pinus keisya* var. *angbianensis*	*Eucalyptus* spp.	*Taiwania flousiana*	*Aluns nepalensis*
Market value	7	9	7	6	10	6
Growth rate	8	8	9	10	8	8
Timber quality	6	8	8	6	10	4
Hardness	10	8	8	7	10	5
Planting scale	3	7	3	4	1	2
History of plantation	10	8	5	6	2	7
Sensitivity to pests and diseases	10	8	8	7	8	10

Note: score 1= lowest preference, 10= highest preference

Conclusion

At least three separate periods of forest degradation have occurred during the 20th century in the watershed. As a result, the forest currently consists primarily of pine plantations that have been established in recent years and which are low in biodiversity. Efforts are under way to introduce fruit tree seedlings, agroforestry practices, and nitrogen fixing plants to improve the forest resources and soil fertility in the community owned forests. In addition, rehabilitation programmes are under way to stabilise slopes in the lower parts of the watershed. Initiatives have also been taken to produce improved tea seedlings for the tea gardens in the central portion of the watershed.

During the implementation of the first phase of PARDYP, modest subsidies were provided to establish local nurseries and bamboo plantations. Some free fruit tree seedlings and forest plants were also provided. These were considered as positive incentives to increase the motivation, enthusiasm, and participation of local farmers in the reforestation efforts. In the future, greater efforts will be made to provide training to improve the abilities of the farmers to manage the timber forests, fruit trees, and tea plantations. The establishment of community-based forest user groups will be crucial for sustainable forestry development in the watershed.

Acknowledgements

These PARDYP forestry activities were implemented with the support of the project team members and many thanks are given to these people for their significant contribution. The authors are also grateful to Prof. Yang Qixiu of Chengdu Institute of Biology and Dr. Tang Ya of ICIMOD for their invaluable advice and assistance. Finally and in particular we would like to thank local farmers for their support and understanding during the implementation of project activities.

Forest Dynamics in Nepal: Quantity, Quality, and Community Forestry Issues in Middle Mountain Watersheds

Hans Schreier[1], Bhuban Shrestha[2], Sandra. Brown[1], and Pravakar B. Shah[2]
[1]Institute for Resources and Environments, University of British Columbia, Vancouver, Canada
[2]International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

Over the past 50 years the forest cover has changed significantly in the middle mountains of Nepal. A GIS analysis showed cycles of degradation followed by rehabilitation and then again degradation. Unfortunately, because of the intense population pressure, the rehabilitation periods have been insufficient to restore forests to a sustainable level. The changes in forest cover were investigated in one watershed in the middle mountains as an example. The overall changes were identified using maps and aerial photographs, the changes in forest quality were investigated over nine years using a plot study. The dilemma faced by user groups was investigated through a user group survey in another watershed. The results demonstrated that the forest quality in the study area is still declining, as shown by a loss of more than 50 per cent of individual trees. At the same time the tree biodiversity is limited to two major species, there is a lack of groundcover, and the soil fertility in the forest is declining as a result of massive removal of palatable material for animal fodder, litter to support agriculture, and firewood. Turning over the control of forest management to the communities has been claimed as a positive step towards obtaining better management of the forest resources. However, the poorest segments of the society, particularly the women with little access to forests on private land, suffer most because their workload is increasing, and fodder and fuelwood shortages are worse than five years ago. The introduction of native nitrogen-fixing fodder trees into the forest and a well planned collection calendar endorsed by the community is likely to be a better approach than simply restricting access to the forest in the hope of rapid natural regeneration.

Introduction

Much has been written about forest cover degradation in Nepal and the topic has always been controversial. Many authors have warned about the rapid decline in forest cover (World Bank 1979; Eckholm 1975), while others have written about forest improvements (Gilmour 1991). What became obvious in the 1990s was that if the pressure on forest resources continued to increase due to population growth, then it would be difficult to maintain the quantity and quality of forests without major changes in forest policies. Recent changes in national policy aimed at placing forest management control into the hands of communities have been greeted with much optimism in the hope that this will result in an improvement of the forest resources. However, since the demand for forest resources is high and the supply is limited, restrictive access and conservation measures might result in significant hardship, particularly for the poorer people in the mountains. The pressure on the forest resources is most evident in the middle mountain region of Nepal where the population is high and agricultural intensification has resulted in a significant flow of biomass and nutrients from the forest into agriculture. The Jhikhu Khola and Yarsha Khola watersheds are used here as examples to document the forest dynamics in this region. The aims of the paper are to:

- document recent changes in forest cover;
- identify changes in forest quality and biodiversity; and,
- identify interactions and constraints amongst forest user groups.

Historic maps, aerial photographs, and GIS techniques were used to document temporal changes in forest cover in the Jhikhu Khola watershed. Thirteen forest plots were inventoried in 1989 and have been monitored for nine years to document forest quality changes and growth. A user group survey was carried out in the Yarsha Khola watershed to describe the dilemma faced by the user groups in trying to find a balance between excessive use, degradation, and conservation.

Site Description and Methods

The Jhikhu Khola watershed covers 11,000 ha, is located 45 km east of Kathmandu, and is accessible via the Arniko highway. The watershed has a very high population density and due to market access, agricultural production is some of the most intensive in the middle mountains of Nepal. The average crop rotation intensity is 2.4 crops/year and forest resources play an important role in maintaining the agricultural production. Fodder from the forest plays a key role in the production of manure, which is the main source of organic matter input into agriculture, and the ashes from home-kitchen fires are returned into the cropping system. During the dry season, forest litter is collected in very large quantities for animal bedding and is then added to the agricultural soils as compost. The forest cover in the watershed was determined for 1947, 1972, 1981, 1990, and 1996 using historic maps and aerial photo interpretation techniques. All data sets were digitised and incorporated into a GIS system, and the changes in forest cover determined using a GIS overlay technique.

The forest quality and growth measurements were examined using a time series analysis of 13 forest plots of 20x20 m size. A baseline inventory was carried out in 1989 (Feigl 1989) during which every tree was identified, dbh and tree heights were measured, soils and foliar nutrients were analysed, corner trees in each plot were marked with red paint, and the x and y coordinates of each tree within the plot were determined and marked on a georeferenced plot map. Monitoring of tree removal took place every three years, and in 1998 the baseline inventory was repeated to determine overall tree losses, growth rates, and changes in soil nutrient content. The plots were selected to reflect the different forest ownership and forest types in the Jhikhu Khola watershed. A summary of the general site conditions is provided in Table 44. The chemical and physical conditions of the soils in 1989 and 1998 were determined using a composite sample consisting of 15 sub-samples collected randomly within each plot.

Table 44: **Forest Plot Site Conditions**

Plot No.	Elevation (m)	Protection	Dominant Trees
1	800	no	chir pine
2	820	no	chir pine
3	890	yes	chir pine
4	880	yes	sal + chir pine
5	870	yes	Sal
6	930	no	chir pine
7	840	no	chir pine
8	880	yes	chir pine
9	950	no	sal + chir pine
10	910	no	Sal
11	880	no	Sal
12	880	yes	chir pine
13	870	yes	Sal

The dynamics in forest use were examined in the Yarsha Khola watershed, located 190 km east of Kathmandu along the Lamasang-Jiri Highway. The watershed covers an elevation range of 1000-3000 masl and extends over 5500 ha. The changes in the use of the forests were examined in a participatory manner with the Department of Forestry and local user groups. Four types of management were identified: formal FUGs (forest user groups), informal FUGs, national forests, and private forests. In the Yarsha Khola watershed, 12 formal forest user groups manage 29 per cent of the forests, and much of the remainder is claimed by informal FUGs. Information for each user group was obtained from the Department of Forestry (DFO) and from participatory surveys with the user groups. In each case information on the size of the forest, the number of participants in the group, the user rules, and the penalty system were recorded. The actual forest cover classification was derived from 1:25,000 scale aerial photographs and subsequent GIS analysis.

Results

Changes in Forest Cover in the Jhikhu Khola Watershed, Nepal

The forest cover dynamics in the Jhikhu Khola were examined by Schreier *et al.* (1994), and Shrestha and Brown (1995) and revealed that between 1947 and 1981 some 24 per cent of the cover had been removed as a result of deforestation. Activities by the Nepal-Australia Forestry Programme (NAFP) in the early 1980s resulted in a significant increase in forest cover, which resulted in a 10 per cent gain in forest cover between 1972 and 1990. In 1990 and 1996, new 1:25,000 scale aerial photographs were acquired which enabled a more detailed assessment to be made of the forest cover dynamics in the watershed. The results showed a small decrease in forest cover, which was attributed to conflicts during the introduction of democracy in Nepal. Overall the two most dominant forest types were chir pine (*pinus roxburgii*) dominated forests, and sal (*shorea robusta*) dominated forests. Between 1972 and 1996 the forests dominated by pine increased by 680 ha—largely as a result of afforestation, while the sal forests remained relatively constant until 1990 and subsequently increased by 300 ha as a result of natural regeneration. These findings were converted into a historic cover change graph (Figure 31) which shows evidence of a cycle of

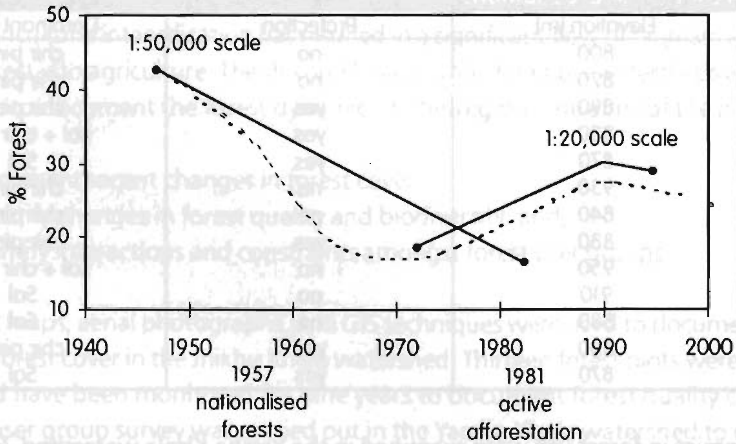

Figure 31: **Historic Changes in Forest Cover**

deforestation followed by afforestation, followed by renewed deforestation. While the most recent rates of deforestation are small, they are nevertheless significant because the afforestation period is usually too short to recover what was lost over the previous period. This results in a downward spiral, which is of significant concern. Community forestry was initiated in 1978, but the programme of transferring national forests to community user groups only accelerated in the mid 1990s. It is hoped that once the management control of the forests is in the hands of community groups, self-imposed restrictions will result in an improvement in forest cover. However, the pressure on the forests is severe and a recent farmers' survey showed that fodder and fuelwood deficits increased between 1990 and 1996. The forest cover analysis only provides information on tree cover, not on tree biomass growth, tree quality, and understorey cover. Changes in these cannot be measured via remote sensing, and forest plot studies have to be undertaken to record these factors.

Changes in Forest Quality in the Jhikhu Khola Watershed, Nepal

The 1989 survey showed that chir pine dominated eight of the thirteen plots and sal forests five. Overall there was a significant loss of trees between 1989 and 1998, but the losses were sporadic. All sal trees were removed from three plots between 1989 and 1994. In two of these plots the removal occurred during the process of introduction of democracy in Nepal in 1993, while the trees in the third plot were removed more gradually over a five-year period.

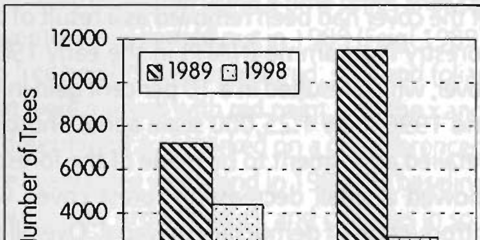

Figure 32: **Change in the Number of Trees in Forest Plots 1989-98**

Sal trees were removed at a much higher rate than pine trees (Figure 32) because sal wood is a much more desirable fuelwood for brick making than is pine. The demand for fuelwood increased significantly between 1989 and 1998 because of rapid population growth (both internal growth and immigration of labourers working in the intensive agricultural system, Brown 1999). This spurred a building boom resulting in a high demand for sal wood to produce local brick.

Of the nine pine-dominated sites (Figure 33) seven showed major losses and only two minor losses of trees over the nine year period. All trees were removed from two of the four sal-dominated plots, while the other two plots experienced large losses (Figure 34). Overall 40 per cent of all chir pine trees and 75 per cent of all sal trees were removed from the 13 sites over the 9-year cycle. These trends clearly show that the forests in the Jhikhu Khola watershed are under intense pressure.

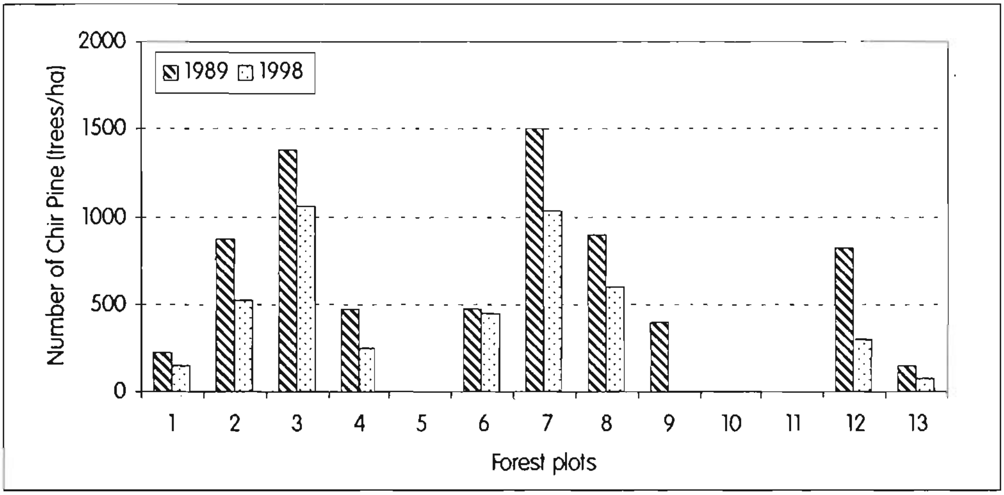

Figure 33: **Losses of Chir Pine Trees in Forest Plots 1989-1998**

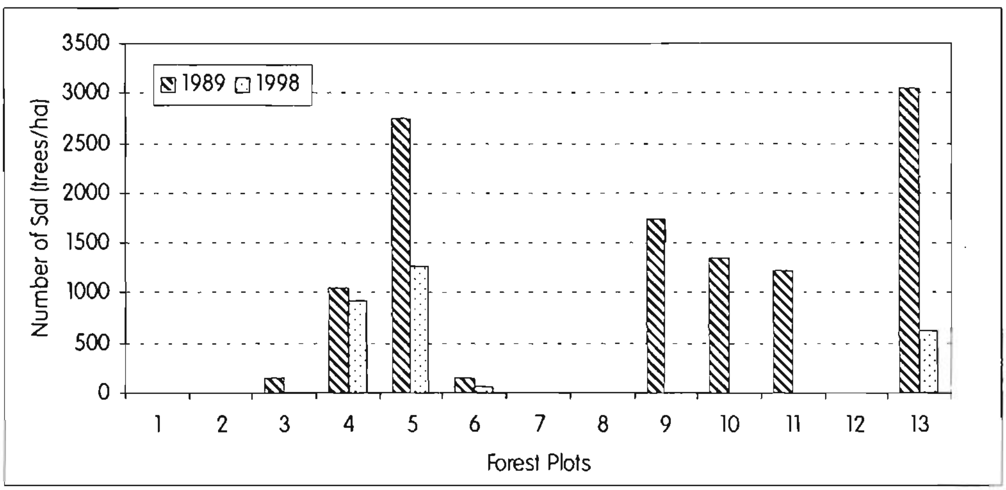

Figure 34: **Losses of Sal Trees in Forest Plots 1989-1998**

In 1998, 98 per cent of all remaining trees in the 13 sites were either chir pine or sal trees. During the nine-year observation period no introduction or regeneration of any other species was observed, and the understorey became degraded.

On the positive side it can be argued that removal of trees is a necessary management practice. As Figures 35 and 36 show, the growth rate of the remaining trees was significant with an average stem diameter (dbh) change from 10 to 40 cm for pine and from 5 to 25 cm for sal. However, the increase in biomass and growth in crown cover could have been significantly higher without the loss of more than 40 per cent of the trees over a nine-year period, since tree spacing was appropriate and no thinning was needed. In addition the biodiversity also decreased because no new trees or species were introduced or regenerated in these plots.

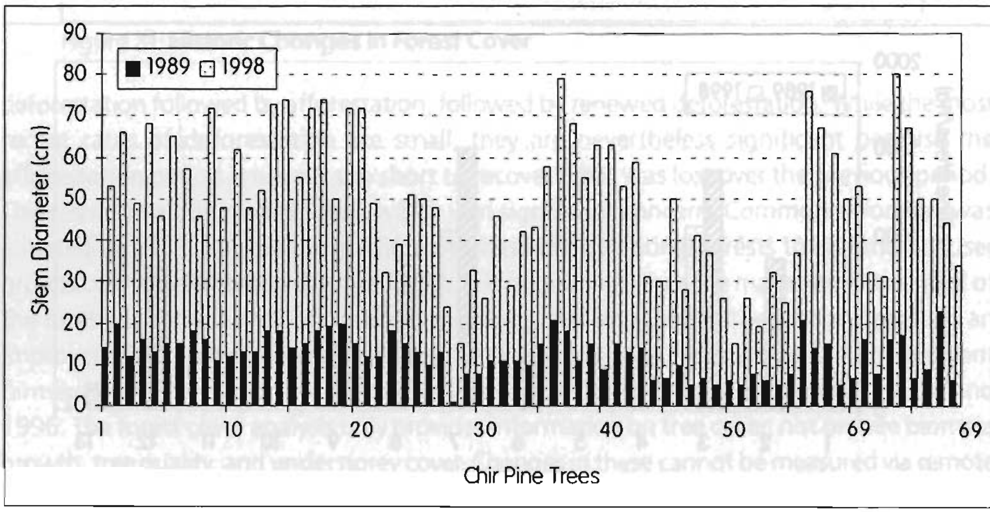

Figure 35: **Changes in Chir Pine Diameter 1989-1998**

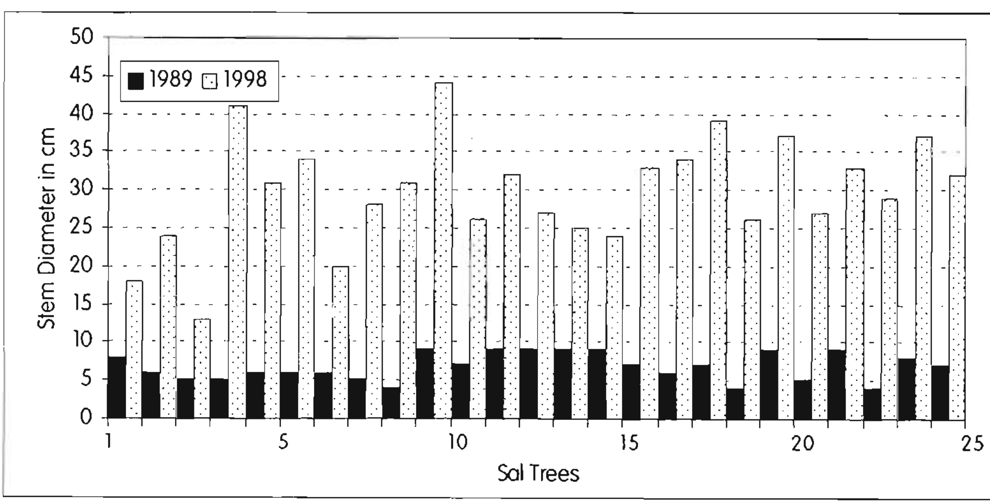

Figure 36: **Changes in Sal Diameter 1989-1998**

Trees were mainly removed for fuelwood and timber. At the same time the demand for forest litter also increased significantly because of agricultural intensification. This removal of biomass resulted in an increased flow of nutrients out of the forest. This is shown by a comparison of the carbon and available phosphorus content in the soils. Overall the percentage carbon content in the soils declined from 0.4 to 0.15, and the available P content from 0.4-0.1 mg/kg of soil (Figures 37 and 38).

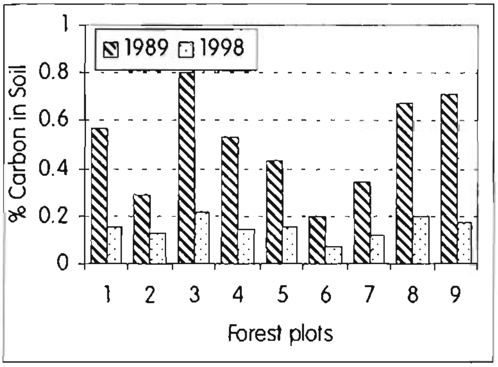

Figure 37: **Decline in Soil Carbon (%) 1989-1998**

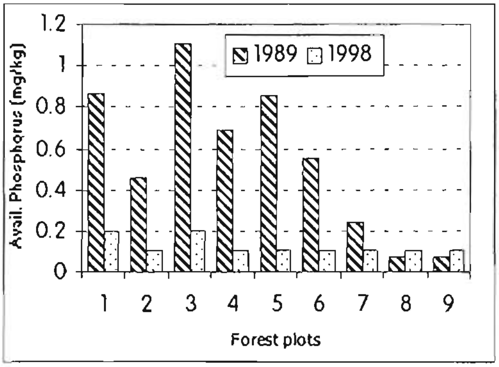

Figure 38: **Decline in Soil Phosphorus (mg/kg)**

Detailed analysis of the tree survival and growth rates indicate that while the overall forest cover increased in the watershed, there were significantly fewer standing trees and no evidence of vegetation diversity or recovery of the understorey. This suggests that the fodder, fuelwood, and litter demand from the forest exceed the growth capacity and sustainability of the forest system, as was evident from the loss of trees, biodiversity, soil quality, and soil nutrient pools. The decline in tree numbers and soil nutrients raises the question of how to sustain forests under the increasing population pressure in the middle mountains of Nepal. Many suggestions have been made that externally managed forests (under the control of the national government) will not be managed as effectively as those where forest management is under the control of community user groups. Since the introduction of democracy in Nepal, many forests have been turned over to community groups; the management difficulties faced by these user groups are discussed in the following paragraphs.

Constraints Faced by Forest User Groups in the Yarsha Khola Watershed, Nepal

The critical problems of sustainability faced by forest user groups (FUGs) were investigated in the Yarsha Khola watershed (Brown 1999). Twelve formal user groups were identified in the watershed. Forest access is typically restricted when a new FUG is formed. Collection of fodder (green leaves) is not currently permitted by 11 of the 12 formal FUGs, and fuelwood collection is not permitted by 8 of the 12 groups. Informal FUGs also restrict access, with many forests closed for five years. When forest access is permitted, collection periods are typically restricted to 1-2 weeks per year for fuelwood, and less than one month for fodder. This shows that local residents are aware of the potential degradation problems and that they take active steps to protect the remaining resources.

However, evidence from the Yarsha Khola watershed indicates that restricted access to community managed forests as a result of establishing user group rules results in fuelwood and fodder shortages that extend over 40 weeks of the year. These shortages are most prevalent at mid to low elevations where forests are limited in extent and consist largely of pine plantations (not useful for animal fodder). The restricted access to government-owned forests shifts the pressure to private lands. The majority of animal fodder and bedding material (litter) is collected from terrace risers, crop residues, and shrubs and fodder trees on private land. Government forests (formal, informal, and national management) are an important source of fuelwood, but access has been limited through the establishment of community forestry. The majority of women (86-91%) indicated that the collection of fuelwood, fodder, and litter is now more difficult than five years ago when the forests were primarily under the control of the national Forestry Department (Table 45).

Table 45: **Forest Access Restrictions**

Management Regime	Fuelwood		Fodder		Litter	
	No. closed	Average Access (days/year)	No. Closed	Average Access (days/year)	No. Closed	Average Access (days/year)
Formal FUGs (n=12)	8 of 12	7	11 of 12	2	5 of 12	45
Informal FUGs (n=11)	9 of 11	32	9 of 11	3	6 of 11	44

The collection of forest products is largely the responsibility of women and girls. In over 90 per cent of the households females are involved in the collection of animal fodder, litter, and fuelwood, while males are typically involved in fuelwood collection only. Women and girls typically make one trip per day to collect fodder and litter, and one trip per week to collect fuelwood. Community forestry initiatives have restricted the access of women to forest products. The new restrictions are quite severe, as shown in Table 46, with fodder access limited to 2-3 days per year and fuelwood to 7-32 days per year. Only litter collection is somewhat more open. Closures have created additional workloads for women who are forced to collect fodder, litter, and fuelwood from alternative sources, and households with limited land are severely affected.

Table 46: **Women's Perception of Forest Product Collection**

Compared to Five Years Ago	% Households Reporting		
	Fuelwood	Fodder	Litter
More difficult now	91	86	90
Same	7	8	4
Easier now	2	6	6

The survey showed that almost all households that have access to private lands rely on these for fodder, litter, and fuelwood (Table 47). As a result of the creation of community forestry, it is now evident that some 45 per cent of households do not have access to formal or informal forests as a result of either forest closure or exclusion from the FUGs.

Table 47: **Collection of Forest Products by Source**

Source	% Households Using		
	Fuelwood	Fodder	Litter
Private land	87	98	97
Formal FUGs	25	29	19
Informal FUGs	32	2	10
National forest	1	2	0
Buy	3	3	0

These results clearly show the dilemma of Nepal: how to protect the forest without increasing the hardship of the poorer fraction of Nepalese society, the female farmers with no access to private land who are now restricted from using the community forests. There are no easy solutions to this dilemma, but creative afforestation with nitrogen fixing fodder trees is one of the options. As shown by Schreier *et al.* 1999, rehabilitation of degraded land offers some limited possibilities, but such activities are not easy, require external inputs, and certainly will not improve the fodder and fuelwood shortages in the short term. Active afforestation of existing community forests using native nitrogen fixing fodder trees and nitrogen fixing grasses, rather than extensive forest closures, is an alternative that should be considered.

Summary and Conclusions

The research described in this paper clearly shows the dilemma faced by Nepali people in the middle mountains. Excessive use of forests leads to degradation, loss of biodiversity, shortages of fodder and fuelwood, a decline in the nutrient pool, and a long-term decline in forest productivity. Protection of the forest by community groups will help in re-establishing the forests, but such processes are long term and create significant hardship for the poorest fraction of society. The analysis in the Jhikhu Khola watershed showed that the forest cover changes are cyclic, and in spite of transfers of management control from the national government to the community it is evident that the forest cover has not improved significantly in the past few years. In addition, the forest quality is degrading as shown by the loss of biodiversity and soil nutrients. The lack of fodder and fuelwood is widespread, and the majority of female farmers noted that the availability of these resources is declining resulting in an increase in the workload of women.

Restricting access to conserve forests is the obvious answer promoted by the Forestry Department and the community groups, but this creates a new problem and poor farmers that have no access to private forests suffer the most. We suggest that afforestation with nitrogen fixing fodder trees and grasses be promoted in community forests, rather than simple closure for natural regeneration. With community involvement and proper enforcement of rotational access it is possible to regenerate biodiversity and provide short-term biomass for those female farmers who are under the greatest stress. These are not easy solutions and a delicate balance has to be achieved between protection and limited or rotational use. Only a massive educational effort, a reduction in population pressure, and a focus on the needs of the poorer women, can set the stage for improving the production and sustainability of the community forests in the region.

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Rehabilitation of Degraded Lands

Pravakar B. Shah[1], Hans E. Schreier[2] and Gopal Nakarmi[1]
[1]International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal,
[2]Institute for Resources and Environment, University of British Columbia, Vancouver, Canada

Abstract

Degraded sites are difficult to rehabilitate because of their adverse chemical and physical condition and the large inputs required to restore the physical properties and the soil nutrient pool. Experiments conducted in the Jhikhu Khola watershed showed that fodder trees could be successfully established in hedgerows on degraded non-red soils on quartzite, but that this was a significant challenge on degraded red soils (on phyllite), and extremely difficult on non-red soils on saprolite. Selected groundcover and grasses were established on red soils and the effect of adding various combinations of lime and manure tested. Lemon grass in particular was found to be a successful coloniser on these highly acid soils. Rehabilitation of the nutrient pool with litter additions alone was found to be very slow, but significant improvements were achieved in the carbon pool and soil structure following a two-year period of continuous addition of litter (once every six months). The incorporation of locally grown thetonia species improved the carbon content and soil structure, but had little affect on the soil pH or availability of phosphorus. It seems that addition of litter and lime is the best treatment to overcome the adverse chemical conditions of red soils.

Introduction

Natural instabilities are common in the middle mountains of Nepal. The main causes of slope failures are the excessively steep topography, the highly weathered and fractured bedrocks, the continuous tectonic uplift of the rock formations, and the monsoon climate. If to this is added the very intensive land use and the limited external inputs into the forested and agricultural systems, it is of little surprise that land degradation is evident in large areas, including in the two watersheds in the middle mountains of Nepal, the Jhikhu and Yarsha Khola watersheds, that are being studied as examples in the PARDYP project. Seven per cent of the Jhikhu Khola watershed was classified as degraded land on the basis of interpretation of aerial photos and GIS analysis. The definition used for degraded land included all areas with minimal permanent vegetation cover on landslides, rilled and gullied surfaces, areas subject to frequent sheet erosion, and continuously eroding riverbanks. The causes of the degradation are difficult to assess since many slope failures are likely to be the result of a combination of natural instabilities caused by uplift, excessive rainfall, and human-induced degradation resulting from overgrazing, deforestation, and insufficient inputs of organic matter and nutrients. While the overall extent of the degraded areas is small, the impact on the rest of the watershed system is magnified. The degraded areas in the watershed do not produce any biomass and because of the lack of protective vegetation cover much more sediment is produced from these source areas than from agricultural and forested land (Carver 1997). An estimated 30 to 40 per cent of the annual stream sediment load in the Jhikhu Khola watershed originates from degraded lands. This sediment causes many problems clogging irrigation channels and silting up reservoirs downstream from the source areas. A significant portion of the soils eroded from upland areas is recaptured via irrigation water in the lowlands, but whereas the soils eroded from agricultural fields provide a nutrient enrichment that is of significant benefit to the downstream rice farmers (Schreier *et al.* 1995, 1998), the sediments originating from degraded lands have a very low nutrient content and are of little benefit.

It is imperative that degraded sites are rehabilitated because the demand for agricultural land is high and the off-site impacts are substantial. Rehabilitating degraded sites is highly challenging, however, and in the current situation farmers have little incentive to initiate such projects because the human effort needed is large, there are widespread labour shortages in the watershed, and there are few short-term benefits because the initial biomass yields are very small. Rehabilitation experiments were performed to help improve our understanding of what processes are successful in stabilising the soils and how the soil fertility can be improved.

Characteristics of the Degraded Sites

A three hectare site at 900m elevation on quartzite, phyllite, and siltstone/saprolite parent material was selected for the rehabilitation experiment. The site is shown in Figure 39. It had marked gullies and was heavily eroded. About 60 per cent of the site consisted of red soils, which are particularly sensitive to degradation.

The red soils in Nepal tend to develop on stable land forms and represent the oldest and most leached soils in the country. Once degraded they are difficult to rehabilitate. They have chemical and physical conditions that inhibit biomass production in many different ways. Red soils originate predominantly from phyllitic bedrock and are dominated by iron and aluminum oxides, with kaolinite as the dominant clay mineral. These soils have a relatively low cation exchange capacity and lack basic cations (Ca and Mg), they have low pH values, and because of the acidity and dominance of Al and Fe the availability of phosphorus is very limited (Schreier *et al.* 1999). As

Figure 39: **Degraded Red Soil Site**

degraded sites have no biomass cover the carbon and nitrogen contents are also very low. The values of some of the chemical parameters of the red and non-red soils in the watershed are given in Table 48. The physical structure of the red soils is also poor with low infiltration and percolation rates and frequent surface crusting. Rainfall intensity often exceeds the infiltration and percolation rates at these sites leading to accelerated surface erosion.

Table 48: **Contrast in Soil Chemistry between Red and Non-red Soils, Bela Subcatchment**

Variable	Red Soil (n=90)	Non-red Soil (n=110)
pH	4.9	4.8
CEC (cmol kg-1)	13.0	8.9
Exchange Ca (cmol kg-1)	3.97	3.56
Exchange Mg (cmol kg-1)	1.77	1.09
Exchange K (cmol kg-1)	0.37	0.21
Base Saturation (%)	46.8	55.8
Available P (mg kg-1)	9.8	22.1
Carbon (%)	0.99	1.00

Rehabilitation Experiments

Three different rehabilitation experiments were performed:

- a fodder tree hedgerow experiment;
- a grass cover experiment with different soil treatments; and
- an organic litter experiment to rehabilitate the soil nutrient status.

The first experiments were started in April 1996.

Fodder Tree Hedgerow Experiment

The degraded site was divided into sixteen 30x30 metre sections whose edges approximately followed the contour lines. Although the plan of the sections was regular, the sections were actually highly variable as the site was heavily gullied, sloping, and irregular. The edges of the sections approximately followed the contour lines across the site. The type of soil and parent material varied across the site and the sections were defined according to the major soil type/parent material in each. Essentially red (and pink) soils were found on phyllite parent material, and yellowish brown soils on quartzite, siltstone, and sandstone. There is very little (non-red) soil cover on saprolite parent material. Quartzite has the advantage that it tends to be deeply cracked, offering a secure hold for tree roots as well as potential caches of water. These characteristics are unevenly distributed, however, leading to a variation across any site in the potential for supporting tree growth.

In each section one of seven different types of six month-old fodder tree seedlings was planted along both sides of one metre wide strips down the length of the plot (with a two to three metre spacing between seedlings) in the form of a hedge (a total of approximately 60 trees per plot). The hedgerow form of planting was chosen as it is a particularly successful way of stabilising a slope and at the same time leaves a clear space that can be used to grow other crops. The tree species tested were *Dalbergia sissoo, Albizia lebbeck* (kalo siris) and *Albizia procera* (rato siris), *Litsea monopetala* (kutmiro), *Bauhinia purpurea* (tanke), *Melia azedarach* (bakaino), and *Acacia catechu* (khair). The constraints of the site meant that it was not possible to plan a strictly controlled experiment with single tests or replicates of each type of tree on each type of soil. Rather an attempt was made to discover whether a) fodder trees of the types preferred locally (and available) could be established successfully in hedgerow form on this degraded site, and b) any type of tree could be grown successfully in the most difficult parts of the site and the site successfully rehabilitated overall. Thus, for example, siris and sisso trees were not planted on saprolite parent material as previous experience indicated that these species would not grow successfully on such soil, and other potentially more promising species were tested on this particularly disadvantageous area. The experimental design is shown in Table 49 and shows the type of fodder trees planted on the three types of weathered parent materials: saprolite/siltsone (non-red soil), phyllite (red soils), and quartzite (non-red soil). One kilogram of manure was added with each seedling in order to increase tree survival rates.

Table 49: **Nitrogen Fodder Tree Experiments, 30 X 30m Plot Design**

A1 Siris Quartizite	Soil Rehabilitation Experiment			
B1 Sissoo Quartzite				
D1 Tanke Quartzite	D2 Siris Red Soil (phyllite)	D3 Kutmiro Mixed	D4 Bakaino Saprolite	D5 Sissoo Red Soil (phyllite)
E1 Siris Quartzite	E2 Bakaino Red/mixed	E3 Tanke Saprolite	E4 Kutmiro Saprolite	E5 Siris Red Soil (phyllite)
Soil Rehab. Experiments	F2 Sissoo Quartzite	F3 Khair Quartzite	F4 Bakaino Quartzite	F5 Sissoo Red Soil (phyllite)

Note: The name of the tree species planted, and the type of soil or parent material are shown for each plot. The 'soil rehabilitation' plot experiments are described in section c).

The number of hedgerow trees remaining and the average height after two and a half years are shown in Figures 40 and 41. The average tree heights on the three types of parent material are shown in Figure 42. The tree survival and growth varied considerably between the sections, but overall the establishment of hedgerows was significant. There were large differences in biomass production between parent materials. The best results were obtained on quartzite materials, while the red soils on phyllite showed less good and the saprolite/ siltstone very poor results, although even in these plots a small number of trees survived growing very slowly.

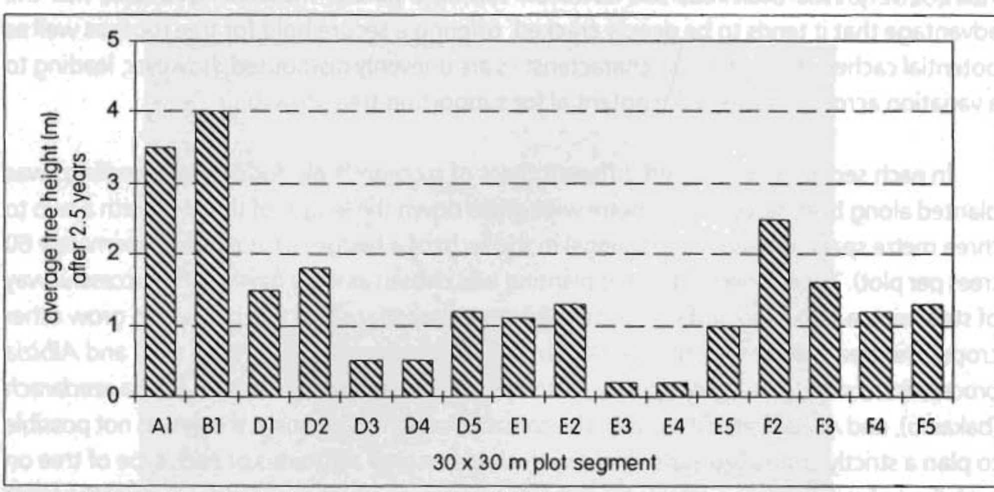


Figure 40: **Number of Hedgerow Trees after 2.5 Years**

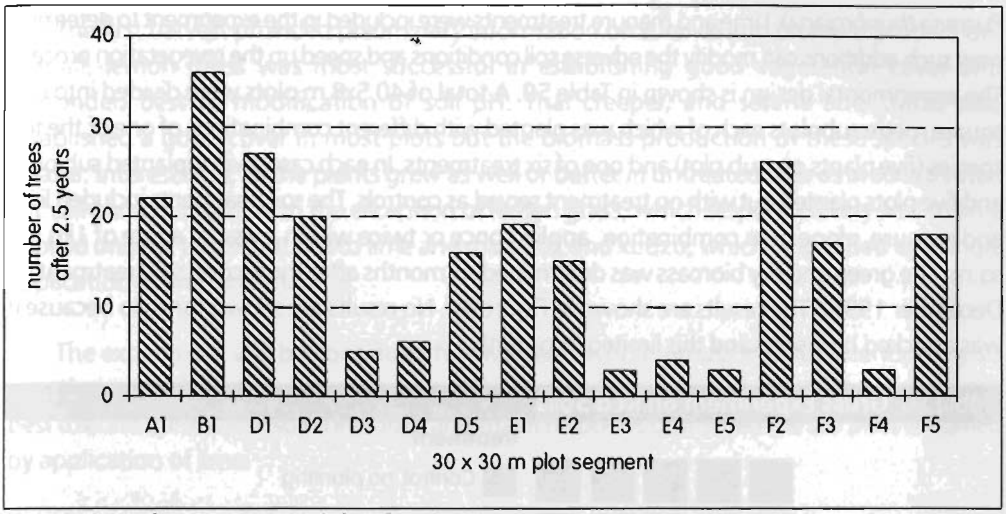


Figure 41: **Hedgerow Tree Height after 2.5 Years**

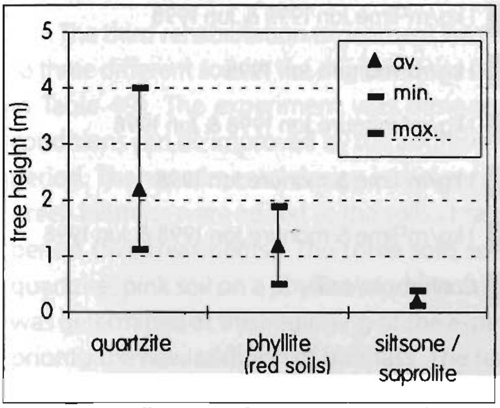


Figure 42: **Influence of Parent Material on Hedgerows**

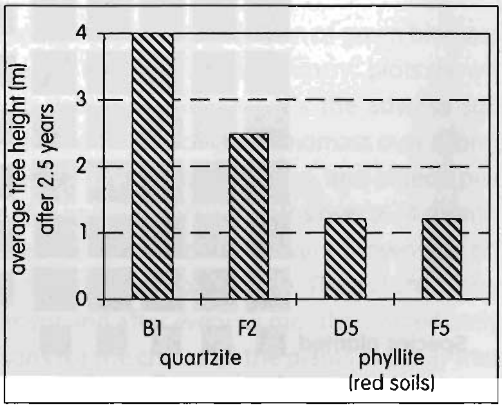


Figure 43: **Performance of *Dalbergia sisoo***

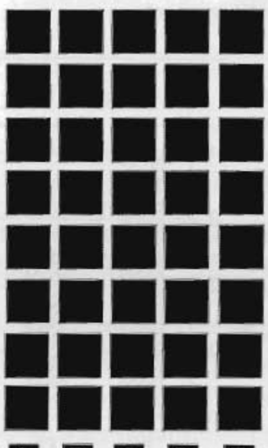
Of the seven fodder species, *Dalbergia sissoo* was the most successful with trees reaching average heights in the best sub-plots of up to 4 m within 2.5 years (Figure 43). The other successful species were *Albizia lebbeck* (kalo siris) and *Albizia procera* (rato siris). *Bauhinia purpurea* (tanke) and *Acacia catechu* (khair) survived well but grew only slowly on quartzite, *Melia azedarach* (bakaino) survived well but grew only slowly on red/mixed soil. As expected none of the three species tested on saprolite did well, although *Melia azedarach* (bakaino) showed fractionally better survival and growth rates than *Bauhinia purpurea* (tanke) and *Litsea monopetala* (kutmiro).

Grass Cover Experiment with Different Soil Treatments

A second experiment was started in 1998 on red soils (parent material phyllite) using perennial ground cover species such as lemon grass (*Cymbopogon flexousus*), *Setaria ancep*, stylo (*Stylosantes quianensis*), Thai creeper (Golden Button), and Chinese creeper (kudzu or

Pueraria thunbrgiana). Lime and manure treatments were included in the experiment to determine how such additions can modify the adverse soil conditions and speed up the revegetation process. The experimental design is shown in Table 50. A total of 40 5x8 m plots were divided into one square metre subplots each of which was planted with different combinations of one of the five species (five plants per sub plot) and one of six treatments. In each case, five unplanted sub plots and five plots planted but with no treatment served as controls. The soil treatments included lime and manure, alone or in combination, applied once or twice within a year at a rate of 1 kg per sq.m. The green and dry biomass was determined six months after the second soil treatment (in December 1998). The results are shown in Figure 44. No results are shown for stylo because it was attacked by insects and this limited its growth.

Table 50: **Grass Experiment on Red Soils**



Treatment

1 Control, no planting

2 1 kg/m² lime Jan 1998

3 1 kg/m² lime Jan 1998 & Jun 1998

4 1 kg/m² manure Jan 1998

5 1 kg/m² manure Jan 1998 & Jun 1998

6 1 kg/m² lime & manure Jan 1998

7 1 kg/m² lime & manure Jan 1998 & Jun 1998

8 Control, planted

Species planted A B C D E

A = Lemon Grass (*Cymbopogon flexousus*) 5 plants/m²
B = Setaria (*Setaria ancep*) 5 plants/m²
C = Stylo (*Stylosanthes quianensis*) 5 plants/m²
D = Chinese Creeper Kodzu (*Pueraria thunbrgiana*) 5 plants/m²
E = Thailand Creeper - Golden Button 5 plants/m²

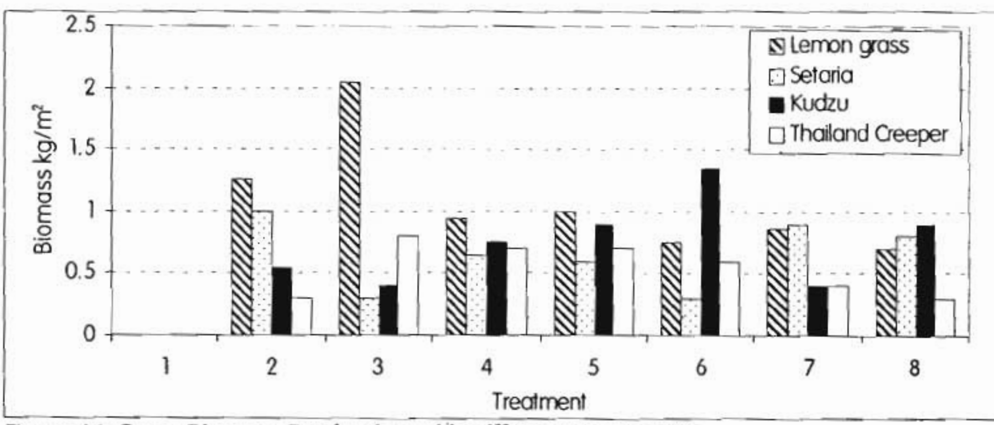


Figure 44: **Grass Biomass Production with Different Treatments**

The first harvest provided preliminary information on survival and biomass production. Overall, lemon grass was most successful in establishing good vegetation cover and responded best to modification of soil pH. Thai creeper, and setaria and kudzu also established a good cover in most plots but the biomass production of these species was smaller. Interestingly, all the plants grew as well or better in untreated soils as in soils treated with all combinations, with the exception of lemon grass, which responded very well to lime applied once or twice (but not to lime and manure), and kudzu, which responded to a single application of lime and manure.

The experiment will be continued for two years with biomass measurements every six months and soil chemical analysis every 12 months. So far it seems that lemon grass can best tolerate the adverse soil conditions and that it responds best when the soil pH is modified by application of lime.

Soil Fertility Rehabilitation through Additions of Organic Litter

The third rehabilitation experiment was based on continuous addition of green biomass to three different soils at the degraded site (in the 'soil rehabilitation experiment' plots shown in Table 49). The experiment was designed to determine how rapidly the adverse soil conditions can be improved by the addition of different types of green biomass over a long period. The experimental design is shown in Table 51. Thetonia, sunhemp, and pigeon pea green biomass were added to the soils at rates of 2 kg/m^2 every six months over a 24 month period (five treatments). The three soils selected for the experiment were brown soil on quartzite, pink soil on a phyllite/saprolite mixture, and red soil on phyllite. The soil chemistry was determined at the beginning of the experiment and after every six months, immediately prior to the new addition of biomass. The reasons for the choice of the plants were: a) that sunhemp and pigeon pea both grow fairly well on degraded red soils so that sufficient green biomass could be grown locally for the experiment; and b) that thetonia, which originates from the Philippines, can be grown on quartzite dominated sites and has been used successfully as an organic matter soil amendment in the Philippines and in Kenya. Locally established sites served as the continuous source of biomass for the experiment.

The green biomass was incorporated into the 0-15 cm surface layer of the soil. After six months a well-mixed bulk soil sample was collected for each plot by combining 20 sub-samples taken in the plot at the same depth. No plants were grown at the site and occasional

Table 51: **Restoration Using Organic Matter, Experimental Design**

Brown Soil	**Red-Pink Soil**	**Red Soil**
Plot 1 Thetonia litter 2 kg/m^2	Plot 1 Thetonia litter 2 kg/m^2	Plot 1 Thetonia litter 2 kg/m^2
Plot 2 Sunhemp litter 2 kg/m^2	Plot 2 Sunhemp litter 2 kg/m^2	Plot 2 Sunhemp litter 2 kg/m^2
Plot 3 Pigeon Pea litter 2 kg/m^2	Plot 3 Pigeon Pea litter 2 kg/m^2	Plot 3 Pigeon Pea litter 2 kg/m^2
Additions: April 96, October 96, April 97, October 97, April 98 Soil sampling: before each new addition		

weeds invading the site were removed. The soils were analysed for pH, carbon, available phosphorus, and exchangeable cations using standard methods as described by Page *et al.* (1982).

Typical results are shown in Figures 45 and 46. The three soils reacted differently and, as expected, the changes in soil conditions took place at a relatively slow rate. There was a natural fluctuation in the values, but a clear trend could be observed after 24 months at which time addition of thetonia biomass had resulted in a tripling of the soil carbon content, and the other two treatments had doubled the soil carbon content. None of the treatments influenced the soil pH significantly, and while the available P increased in brown soil, no effect was observed in the red and pink soils. It seems possible that the high concentrations of extractable Al and Fe (ammonium oxalate and citric dithionite-bicarbonate) are responsible for fixing any available P that is released from the decomposition of the organic litter. The soil structure in the red soils became gradually more granular following the addition of organic matter, thus improving the soil structure and water infiltration capacity.

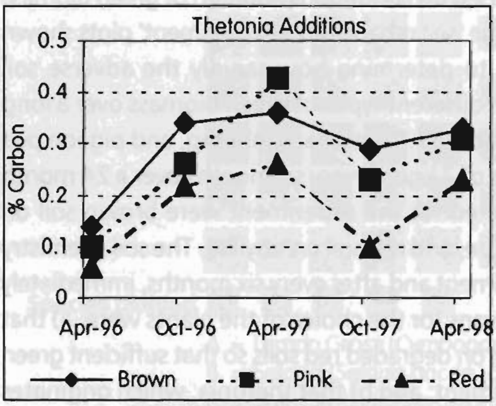


Figure 45: **Changes in %C Following Thetonia Incorporation**

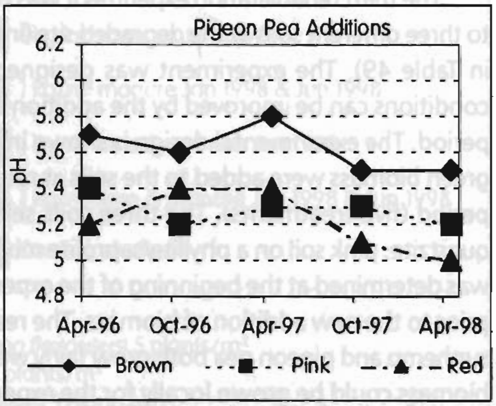


Figure 46: **Changes in pH Following Pigeon Pea Incorporation**

Conclusions

Degraded soils are difficult to rehabilitate. The experiments conducted in the Jhikhu Khola watershed showed that it was not easy to establish fodder trees in hedgerows on red soils, but the results were sufficiently encouraging to prompt further attempts. *Dalbergia sisoo* performed particularly well on the degraded sites on non-red soils on quartzite, reaching tree heights of up to four metres over a 2.5 year period. Various species of perennial ground cover were successfully established on red soils but biomass production was low. Addition of lime improved the survival and biomass production of lemon grass considerably, resulting in the production of more than two kg/m² of dry biomass over a six-month period. Setaria, Thai creeper, and Chinese creeper also survived well in amended red soil and untreated red soil but produced lower biomass. Addition of locally grown green litter (thetonia, sunhemp, pigeon pea) to red, red-pink, or brown soils improved the soil carbon pool but had little effect on soil pH. Available P was improved in the degraded brown soils but not in the red soils. Extractable Al and Fe probably fixes any P released from the organic fraction. Additions of thetonia elicited the most significant soil improvement, but even after four additions of green biomass over a 24 month period, the increase in soil carbon was small (from 0.1 to 0.3%). Improving the overall soil nutrient pool is a slow and tedious process.

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Community-based Energy Planning and Management in the Yarsha Khola Watershed, Dolakha District, Nepal

Kamal Rijal[1] and Rajan Thapa[2]

[1] Renewable Energy Specialist, International Centre for Integrated Mountain Development (ICIMOD)

[2] Mr. Thapa (Research Associate, Centre for Rural Technology, Kathmandu) was deputed to PARDYP to carry out field-level activities on community-based energy planning and management in Yarsha under the supervision of Dr. Rijal

Abstract

This paper briefly describes the process of a community-based energy planning and management activity that was tested and implemented in one of the PARDYP watersheds in Nepal. The main actors in such a process are the beneficiaries themselves, in particular women as they are the managers of the household energy systems. The extension worker has the role of facilitator. Eight main components of the activity were identified during programme implementation: (i) entry into the community; (ii) community mobilisation and confidence building; (iii) interaction with district level line agencies for micro and macro linkages; (iv) understanding the energy consumption patterns and the technologies employed; (v) assessing the availability of energy resources; (vi) balancing energy consumption and resource availability; (vii) examination of the suitability of renewable energy technologies (RETs); and (viii) implementation of selected RETs. This paper examines the issue of replicability and sustainability of the approach in the context of mountain communities and identifies the key lessons learned during programme implementation. The conclusions drawn were as follows. 1) The community-based energy planning and management approach is an effective mechanism for bringing together different stakeholders—villagers, researchers, extension workers, promoters, support institutions, manufacturers, and experts—and enabling them to arrive at consensus decisions, with each stakeholder feeling that they have gained something from the agreement (positive sum game). 2) In order to establish good rapport with communities, it is very important that the research facilitator be calm, patient, persuasive, and results-oriented. 3) Both community members and the research team benefited from enhancing their knowledge, skills, and awareness of RETs. 4) Community-based energy planning and management is an excellent tool for identifying the problems, priorities, needs, and aspirations of communities, and the presence of a research facilitator helps communities to solve problems by themselves.

Background

The increasing deficit of available energy resources (primarily biomass) and the non-availability of, or lack of access to, modern energy forms for household, commercial, and industrial use, not only hampers the fulfilment of basic minimum energy needs but also limits the economic growth potential of hill and mountain communities. Excessive and inefficient use of various forms of energy lead to environmental deterioration and a plethora of negative environmental and ecological consequences. The People and Resource Dynamics Project (PARDYP) of ICIMOD is being implemented in five watersheds, one of which is the Yarsha Khola watershed in Dolakha District, Nepal. PARDYP is developing scientific data sets related to the dynamics of change at watershed level, and has recognised that over exploitation of forest resources as fuel has contributed towards reducing soil fertility, farm productivity, and water availability, and increasing siltation and landslides, as well as exacerbating the already heavy workload of mountain women. This recognition led to the implementation of a community-based energy planning and management activity in the Yarsha Khola watershed (hereafter referred to as 'Yarsha'), which is situated some 190 km east of Kathmandu.

The main objective of the programme was to facilitate selected communities within the project area to plan and implement selected renewable energy technologies (RETs) so that they might be better able to meet their energy needs. The implementation of various energy programmes is expected to reduce the increasing pressure on natural resources (primarily biomass) and provide opportunities for communities to diversify their income generating economic activities. It is hoped that identification and implementation of RET programmes will enhance the capability of communities, extension workers, CBOs, and the PARDYP project team, to plan energy needs and implement energy programmes, and will raise awareness of RETs.

The activities were carried out over a period of nine months. The Centre for Rural Technology/Nepal (CRT/N), a private institution involved in promoting decentralised renewable energy technologies, was engaged for the project with professional support from ICIMOD's Renewable Energy Specialist. The role of CRT/N was to act as a research facilitator in the identification of energy needs and resources, and to ensure the active participation of community members. At the same time, awareness of energy alternatives was promoted, and information on various technological options, the level of incentives provided by the government, and the status of manufacturers was provided. The research facilitator was provided with an orientation to ensure that activities were carried out at the community level. In order to be able to understand and explain various energy technologies to the villagers, the research facilitator first reviewed the status of various RETs. In addition, members of the PARDYP team briefed the research facilitator on Yarsha characteristics and the project activities since 1997.

Process of Community-based Energy Planning and Management

Entry into the Community

The first step was to identify and list potential key informants so that information could be collected on villagers' needs and priorities. The first contact persons were the members of savings and credit cooperative groups, since these are successful grassroots institutions (see Box 1). Good rapport with some office bearers in these cooperatives helped consolidate communication of the objectives of community-based energy planning and management. During this phase, PARDYP hydro-met readers (local residents employed to take the regular readings at hydrological survey sites) located in different areas of the watershed were instrumental in providing further information on potential key informants, village leaders,

BOX 1

Bhabisya Nirman Women Cooperative Society (BNWCS),

Maina Pokhari, Yarsha Khola Watershed, Dolakha District, Nepal

Jansachetan Cooperative Society (JCS), Kavre VDC, became so popular that a number of cooperatives were established in its wake. One such initiative was the establishment in 1995 of BNWCS, exclusively for women, by Mrs. Krishna Kumari who presently serves as the president. Mrs. Kumari realised that it was difficult for women to participate in JCS as they were unable to contribute the minimum NRs.500 as the share capital, or the monthly deposit of NRs.100. The monthly deposit required in BNWCS varies from NRs.30 to NRs.200 per month, thus allowing the participation of poorer women. At present, they have 310 women members with a total deposit exceeding NRs.600,000. Each member can borrow a maximum of NRs.5,000. Most of the women have borrowed money for livestock rearing. According to most of the borrowers, this had meant that they were able to enhance their incomes and contribute towards the welfare of their family. It had also raised their awareness, confidence, and self-esteem, and had resulted in enhanced leadership and improved management capability of the women in Yarsha. This success was a result of the dynamic leadership of one woman who was sincere in her belief that the status of women in Yarsha could be improved.

Source: Village Level Energy Planning Study of Yarsha Khola, Dolakha (Nepal) - report submitted to ICIMOD by CRT/N, July 1999.

different committee members, and other topics. Project staff also introduced local village residents to the facilitator.

Initially, it was very difficult to make village residents understand the purpose of the energy survey and programme. Even defining energy is a difficult task. PARDYP local staff informed the village residents that this energy programme was one of the project components, thus the energy survey was incorporated into on-going discussions. This meant that the facilitator was able to take advantage of the already established project-community rapport.

Community Mobilisation and Confidence Building

Interaction with Key Informants, Group Leaders, Village Leaders

After potential key informants in the villages had been identified, a series of village walks was conducted and different clusters and settlements observed. During the village walks, a number of informal and formal meetings were held with villagers and village and group leaders in which the following were explained and discussed:

- the objectives of the energy programme;
- the critical role that energy plays in terms of improving community living standards and economic potential;
- information on the various available forms of renewable energy;
- the problems faced by the villagers in terms of energy, and potential solutions to these problems; and
- energy-related experiences of the residents.

The main outcomes of these interactions were a better rapport with key informants and collection of baseline information on local level institutions.

There are several different types of local level institution operational in Yarsha in addition to the village political-administrative bodies. There are 25 forest user groups (formal and informal), 30 local governance programme groups, 12 savings and credit groups (including non-registered), 15 small farmers' development groups, and 10 other informal groups.

Following the walk-about survey, volunteers were identified in each VDC who were willing to take part in the survey and in the energy planning and management activities. These persons showed a keen interest in energy issues and possessed leadership qualities. They were not formally nominated by the community but voluntarily agreed to take on the role of contact person and villager organiser for subsequent meetings. These people basically acted as a bridge between the facilitator and the community for information sharing, awareness generation, and issue identification.

Dialogues/Interactions with Village-level Institutions and Outsiders

Intensive dialogues and interactions then took place with the officials of village-level institutions, informal/formal groups, community leaders, knowledgeable individuals, and line agencies. This further widened and consolidated understanding of the energy issues being faced by the community, both by the researcher and by the villagers themselves. Some villagers mentioned that they had never given serious thought to energy issues and always considered that energy would be available when and where desired. The facilitator was also able to help the communities realise the needs and priorities of different stakeholders and their interests in different types of energy resource and technology. The volunteers acted as enumerators and facilitators during the interactions with the village-level institutions and outsiders.

Interaction with District-level Line Agencies for Micro- and Macro-linkages

Meetings with district-level line agencies such as the District Development Committee (DDC), the District Forest Office (DFO), the District Land Conservation Office, the Agricultural Development Bank (ADB/N), the Nepal Electricity Authority (NEA) branch office, Tuki Sangh, and the REDP district office, assisted background understanding about the situation in the watershed and district and helped to identify areas of mutual interest where it would be possible to work together towards resolving the energy issues faced by the villagers. These agencies showed a keen interest in supporting programmes and initiatives identified by the community if that particular programme fell under their jurisdiction. A team of specialists including the renewable energy specialist from ICIMOD also visited these line agencies, which helped to further consolidate the relationships with these organisations.

Understanding the Energy Consumption Patterns, the Technologies Employed, and the Energy Resource Availability

It is essential to understand the energy consumption pattern, assess the available indigenous energy sources and the availability and access to commercial fuels, and examine the suitability of new and renewable energy technologies before designing intervention programmes. These issues are discussed briefly in the following paragraphs.

Energy Consumption Patterns and the Technologies Employed

The energy use pattern was estimated and various types of end-use devices assessed in five communities within the watershed with the help of a checklist and structured questionnaire. Village residents were also involved in the measurement of fuelwood consumption. Willingness to furnish information and to cooperate with the research was excellent. The communities were selected on the basis of the interest shown by them and the degree of energy stress, with the exception of Maina Pokhari, which was selected because it is the only market centre and demonstrates semi-urban characteristics.

The prevailing energy pattern for the whole watershed is shown in Table 52. The types of device used by different sectors and the sources of their energy are summarised in Table 53.

Table 52: **Total Energy Consumption in GJ per Annum, Yarsha Khola, Dolakha, Nepal (1998)**

Description	Fuel-wood	Agric. Resi-dues	Animal Dung	Hu-man Labour	Animal Labour	Kero-sene	Electri-city	Other	Total	% of overall total
Domestic	164970	3,014	334	NA	0	2,474	695	0	171,487	85
Commercial	1287	0	0	NA	0	0	81	0	1368	1
Cottage Industry	3883	0	0	1293	0	0	237	1418	6780	3
Agriculture	0	0	0	7208	4902	0	20	4758	16888	8
Transport	0	0	0	6123	0	0	0	77	6200	3
Total	170089	3014	334	14624	4902	2474	3507	6253	202723	100
Per cent	84	1	0	7	2	1	1	3	100	

Source: Village Level Energy Planning Study of Yarsha Khola, Dolakha (Nepal); report submitted to ICIMOD by CRT/N, July 1999.
Note: NA—not assessed

Biomass (primarily fuelwood) and animate energy (muscle power of human and animals) are the main sources of energy used in the watershed. The domestic sector is the main consumer of energy and the main energy services required are in the form of heat (low-grade energy) for cooking and heating. The demand for energy is expected to grow as a result of both population increase and an increase in the various types of economic activity within these communities. However, poverty hinders the proliferation of renewable energy technologies among low-income groups. The pattern of energy consumption reflects a situation characterised by a subsistence agricultural economy, similar to that which prevails in most of the hill and mountain communities of Nepal.

Table 53: **Energy Technologies Employed in the Yarsha Khola Watershed, Dolakha (Nepal)**

Demand Sectors	Energy Devices	Source of Energy
Household		
Cooking	Traditional/improved stoves, kerosene stoves	Biomass, kerosene
Heating	Tripod stands, electric heaters	Biomass, electricity
Lighting	Kerosene wick lamps	Kerosene
	Biogas burners	Biogas
	Bulbs, tubes	Electricity
Commercial		
Cooking	Traditional/improved stoves, kerosene stoves	Biomass, kerosene
Heating	Tripod stands, electric heaters	Biomass (agricultural residues), electricity
Lighting	Bulb, fluorescent tube	Electricity
Agriculture		
Ploughing	Human and animal mix	Human and animal labour
Weeding/planting	Human labour	Human labour
Irrigation	Human labour	Human labour
Harvesting	Human labour	Human labour
Threshing	Human and animal mix	Human & animal labour
Fertiliser		Manure, chemical ferti.
Rural Industry		
Weaving/mat making	Traditional devices	Human labour
Agro-processing	Traditional ghattas, improved water mills, electric and diesel mills	Water energy, diesel, and grid electricity
Smithy	Traditional equipment	Fuelwood
Furniture making	Traditional equipment	Human labour
Alcohol distilling	Tripod stands	Fuelwood
Others	Electrical appliances	Grid electricity
Rural Transportation		
<u>Within Village</u>		
Agric. Commodities	Human labour	Human labour
Agric. Residues	Human labour	Human labour
Farmyard manure	Human labour	Human labour
Fodder collection	Human labour	Human labour
Agro-processing	Human labour	Human labour
Fetching water	Human labour	Human labour
<u>To and from Village</u>		
Agric. Commodities	Human labour	Human labour
Others	Human labour	Human labour

Source: Village Level Energy Planning Study of Yarsha Khola, Dolakha (Nepal), Report submitted to ICIMOD by CRT/N, July 1999

Energy Resource Estimation

The estimated total primary energy available per annum from different sources is shown in Table 54.

The forest resources were estimated from the information collected through different forest user groups and were cross-checked against the records of the Forest Ranger Office and the PARDYP field office. The energy potential from small streams and rivers was estimated from on-site measurements, the topographical map, and measurements of discharge made by PARDYP. Meteorological stations established by the project provided information on solar radiation and wind velocity.

Table 54: **Total Primary Energy Availability, Yarsha Khola, Dolakha District, Nepal (1998)**

Energy Resources	Sustainable Yield per Annum			Usable Quantity per Annum		
	Natural Units	GJ	Per Cent	Natural Units	GJ	Per Cent
Fuelwood	2,660 tonnes	44,422	8	2,660 tons	44,422	39
Agricultural Residues	12,234 tonnes	154,148	28	537 tons (1)	6,766	6
Animal Dung	17,799 tonnes	194,009	35	2,670 tons (2)	29,103	26
Hydropower	100 kW	3,157	<1	25 kW (3)	394	<1
Solar	45,046 MWh (5)	162,166	29	9,009 MWh (4)	32,432	29
Total		557,902	100		113,117	100

Note:

1. residues suitable for energy purposes like rice husks and corncob—assessed as 5% of the total residue generated
2. 15% of total dung assumed to be available for energy purposes
3. only possible to exploit 25% of potential assuming one unit installed in one stream
4. assuming each household makes 10% of the area of landholding in which the house is set available for solar collection and 50% utilisation efficiency
5. assuming each household makes 25% of the of the area of landholding in which the house is set available for solar collection

Source: Village Level Energy Planning Study of Yarsha Khola, Dolakha (Nepal), Report submitted to ICIMOD by CRT/N, July 1999.

Information on land resources, livestock, human and draft animals, grid electricity, and commercial fuels were collected from the VDC office, key informants, local institutions, and savings and credit groups and were cross-checked with the data available from PARDYP as well as district office records.

Balancing Energy Consumption and Resource Availability

The total energy consumption pattern for primary energy is shown in Figure 47, together with the difference between consumption and usable quantity of that energy.

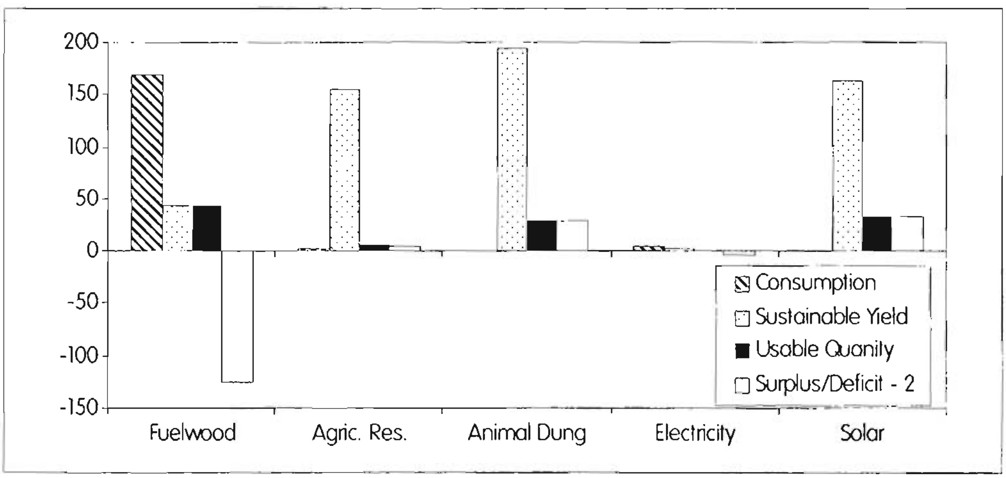

Figure 47: **Energy Consumption, Sustainable Yield, Actual Usable Quantity and Difference Between Consumption and Usable Quantity in Yarsha Khola, 1998**

The figure shows the following.

- Fuelwood consumption is almost four times the sustainable supply.This has led to the encroachment of government forests within and beyond the Yarsha Khola watershed as forest areas near the settlements are under FUG management and are closed for much of the year. Many people consider that the present FUG management practices are not equitable in terms of ethnicity, class, and gender.
- With the increasing difficulty in collecting fuelwood, and if appropriate technological interventions are not introduced, there is a danger that agriculture residues and animal dung will be used for cooking and heating instead of for compost and manure production. This would result in a decline in soil fertility and agriculture productivity, and an increased health hazard from indoor air pollution.
- There is a big potential for exploiting solar energy both for low temperature applications (e.g., hot water production, drying of agricultural produce, green houses for vegetable farming and floriculture, and passive solar heating), and for electricity (for light and for low wattage electrical appliances in areas where grid extension is not feasible).
- Agricultural energy input is dominated by human labour, more than 70 per cent of which is contributed by women— partly as a result of out-migration of men. Human drudgery is high. There has also been a visible shift from cereal crop production to vegetable farming, which has further increased the amount of labour required.

The patterns of energy consumption technologies employed and energy resources available clearly indicate an urgent need for the design of an appropriate energy programme package, both to enhance environmental conditions and to improve people's livelihoods. The analysis indicates that the following interventions would be desirable and should be critically appraised by the local residents.

- Promotion of improved community forest management in such a way that it is more equitable in terms of ethnicity, class, and gender.
- Promotion of more efficient biomass cooking and heating devices to combat fuelwood scarcity.
- Promotion of biomass briquetting technology, as sufficient quantities of suitable agriculture residues are available.
- Promotion of solar home systems, solar driers (for ginger and garlic), and passive solar building technologies.
- Introduction of labour saving devices such as improved ploughs, sprinkler irrigation systems, and agro-processing devices.

Examination of the Suitability of Renewable Energy Technologies (RETs)

Visit to RET Promoters and Manufacturers

Different organisations located in Kathmandu were visited. Information on different RETs related to such points as rated capacity, input and output variables, cost, availability, incentives, and subsidies was collected and provided to the residents of Yarsha.

Motivation/Awareness Campaign on RETs

The residents of Yarsha were informed about options in the field of renewable energy technologies in different ways as mentioned briefly below.

Distribution of Posters and Information Booklets

Posters and booklets on different RETs were distributed to different groups and made available in public places such as the VDC offices and health posts.

Participation in Group Meetings and Discussions

The research facilitator attended several formal and informal group meetings and provided information on various RETs highlighting their suitability for rural hill and mountain conditions. A number of villagers showed keen interest with the most interest being shown in improved cooking stoves, biogas plants, peltric sets, and solar home systems. These meetings were also instrumental in recording energy needs, the various types of energy resources, the technologies at present in use, and the way the communities used each resource.

Orientation Session

Orientation sessions were organised at different watershed locations at the request of the communities.

Observation Tours

Observation tours were also organised for selected members of the interested communities, as it was felt that 'seeing is believing'. Two options were discussed: a) a visit to manufacturers' outlets in Kathmandu; and b) a visit to a place where some of these technologies are operational. The latter was preferred as most of the appropriate technologies existed within Yarsha or nearby, and villagers could arrange to visit these sites on their own. Observation tours were therefore organised locally.

Organisation of an Energy Fair in Yarsha

Only a limited number of people were able to undertake observation tours, and there were some useful technologies that did not exist in the area. This led to the idea of organising an Energy Fair to which relevant organisations would be invited to come and demonstrate appropriate products to the villagers. All parties liked this idea.

A one-day Energy Fair was organised at the PARDYP field office at Maina Pokhari (Kavre VDC) on September 9^{th} 1998. Fourteen relevant manufacturing and retail institutions participated in the fair—most exhibited their products and sent a representative, while some just sent products.

There were 17 technologies on display. They included:

- solar technologies —solar parabolic/box cookers, solar home systems, a solar lantern, a solar low-head water pump, and two types of solar dryers;
- hydropower—peltric set, improved *ghatta*, rice cooker *'bijuli dekchi'*;
- biomass stoves—rice husk stove, metal stove, improved mud stove, *hutaram 'chulo'* stove; and,
- others—corn sheller, basket *'dalo'* thermos, sprinkler, self-help drinking water intake, barbed wire, wire wrench.

Posters, pamphlets, booklets, and photographs of the technologies were displayed and distributed. More than 600 people visited the Energy Fair, and interest was so high that demonstration of the RETs was continued for several more days than originally planned. Residents showed considerable interest in acquiring some of these technologies during the fair. Amongst others orders were given for for 23 solar box cookers, 23 solar home systems, 11 sprinklers, and 6 corn shellers.

The Energy Fair was an excellent opportunity for the people in the watershed to observe different kinds of energy technologies and to gain first hand information from the manufacturers and promoters. Villagers were most interested in those technologies that provided immediate returns and were user friendly; they were not so good at assessing technologies whose benefit would only become apparent after a longer period of time. The demand for solar home electricity systems was also quite high as many villagers wanted to install a television set.

The Community's Perception of RETs

General feedback from the community suggested that most RETs were out of reach of poor and marginal people even with government subsidies. The following arguments underline this.

- There were no government subsidies available for solar home systems (SHS) in Dolakha district because this district is considered to be accessible by road and electricity. The research facilitator persuaded the Alternate Energy Promotion Centre (AEPC, responsible for allocating government subsidies for SHS), to allow a subsidy if there was a demand from Yarsha for more than 10 solar home units. However, the cost of one SHS unit to a farmer even after the 50 per cent government subsidy is NRs 17,000 and this is beyond the means of lower income group households.
- Another viable option for lighting in Yarsha is a peltric set. On average, a household has to bear more than NRs 5,000 of the cost of such a set. This is equivalent to using a wick lamp for 10 years for lighting at an average consumption of three litres of kerosene per month. Thus this technology is considered uneconomic, and is also out of reach of the poorest sections of the community.

- Family-sized biogas plants are a feasible option for middle income groups in villages like Namdu, Mirge, and Gairimudi. The installation cost of a small size plant is about NRs 10,000 after the flat-rate government subsidy of NRs 10,000.

The above-mentioned technologies are suitable for households that are concerned about their quality of life and are willing to save energy and reduce the drudgery of women and children. Most poor people were more interested in RETs that can provide opportunities for earning income (e.g., crop dryers). They believe a decent income must come first before they can consider a cash outlay to improve their living conditions.

Promoting Selected RETs

Improved Cooking Stoves

During the process of needs identification and the motivation and awareness campaign, community members, particularly women, expressed a strong desire to install improved cooking stoves (ICS) because of the fuelwood shortages, which have been exacerbated by the restrictions imposed by the community forestry programme. Women of poor households who do not have trees on their farmland are the main victims as they have neither the capacity to buy fuelwood nor sufficient farm residues and animal dung. Women were convinced that the installation of an ICS would save fuelwood, remove smoke-related problems, and reduce the drudgery of collecting fuelwood from far-off government forest. The installation of an ICS was seen as a priority in most communities in the middle and lower settlements of the watershed where fuelwood availability is a real problem.

In response to these needs, a four-day training programme was organised on the installation of ICSs. Four women were trained, three of them members of FUGs, and one from a savings and credit group (SCG). Soon after completion of the training programme, the trainees became trainers. Each built one stove in their own house as a demonstration unit, and then began installing stoves in different communities in the watershed. The four trained women have reported that requests for their skills have come from different FUG groups, and even from outside the watershed. This reveals the high demand and indicates that this improved technology should be disseminated. The Rural Energy Development Programme Office (REDP) of Dolakha District has committed itself to providing technical backup support and services.

Energy Saving Devices

Improved Wick Lamps

Most people in the watershed use a traditional wick lamp for lighting, which gives poor illumination and emits smoke. Some teashops in Yarsha are using an improved wick lamp that provides more light, emits less smoke, and is more fuel-efficient. The research facilitator demonstrated some improved wick lamps from Jiri and Charikot at the PARDYP field office;

after this demonstration some villagers purchased these lamps at NRs 60 each. In response to the interest shown by the villagers, arrangements were made with a local shop owner in Mirge village to keep these lamps for sale.

Rice-husk Stoves

Two types of rice-husk stove were demonstrated during the Energy Fair, one developed by the National Agriculture Research Council, the other a model available in the local markets. Some villagers wanted to purchase the latter, and five rice husk stoves were distributed.

Sprinklers for Irrigation

Low-head sprinkler systems were one of the most popular of the labour saving devices displayed during the Energy Fair. Although vegetable growing has been promoted by different agencies, sprinkler systems had not been demonstrated. Farmers are increasingly interested in vegetable production in Yarsha for reasons of income. Demand for sprinklers was high, and the researcher facilitated distribution at cost price and made arrangements with some shopkeepers in Charikot to keep these units for sale. The villagers were informed that they can now buy these units in Charikot (36 km from Maina Pokhari, Yarsha - about 1½ hours by bus).

Demonstration of a Baby Hydro Unit

This is a simple device which employs a bicycle dynamo coupled to a metallic runner and can operate 2 torchlight bulbs and a small cassette player or radio. Water from a drinking water tap with a gross head of 16m can operate the system. This device from the CRT/N costs NRs 1,500 perunit. The unit was demonstrated in Mirge and Gairimudi. Many villagers were interested in installing the units, and CRT/N has agreed to make them available.

Demonstration of Solar Devices beyond Yarsha Watershed

CRT/N and Jiri Technical School organised an additional one-day solar exhibition at the Jiri Technical School with support from SDC. People from around Jiri and from Yarsha visited the exhibition.

Ensuring Sustainability of the Energy Programme

The lead role in most of the activities described above was taken by existing institutions, like the FUGs and credit-saving organisations, and by the communities themselves. The research facilitator was instrumental in establishing linkages between the communities, these local-level institutions, and district-level institutions. The Rural Energy Development Programme (REDP) of Dolakha District has the mandate to promote and disseminate RETs and has assured local groups and communities that they will provide technical backup and assistance in obtaining subsidies from the government. The CRT/N also agreed to provide any support required through the PARDYP Field Office. The energy programme in Yarsha will only be sustainable with support from REDP, Dolakha and PARDYP staff. Maintaining contact between the PARDYP Field Office, the resource organisations, and the local-level institutions and communities will be crucial.

Lessons Learned

The community-based energy planning and management activity that was pursued in Yarsha was a useful learning experience for ICIMOD's energy programme, and helped create awareness about energy related issues both within the PARDYP project team and within the watershed and beyond. It also provided an insight into appropriate methodological approaches for carrying out such programmes.

Establishing good rapport with communities is never easy, and it took some time for the research facilitator to understand the community dynamics and to build and win the confidence of the villagers. This task is made more difficult by the fact that energy issues impinge more on women than on men, and that males move seasonally to urban areas for jobs and extra income. Once good community rapport was built, however, the process of participation progressed smoothly. It is very important for a research facilitator to be calm, patient, persuasive, and results-oriented.

The community-based energy planning and management approach employed proved to be an effective mechanism for bringing together different stakeholders—villagers, researchers, extension workers, promoters, support institutions, manufacturers, and experts. Once different stakeholders enter into an open dialogue, misinformation and suspicion among stakeholders are reduced, and an approach can evolve for managing and maintaining rural energy systems on a sustainable basis.

Women's life tends to be one of drudgery, with 12-15 hours of heavy work per day, thus it was very difficult to convince women to participate in an energy programme which focused primarily on improving living standards. There is a crucial need to identify renewable energy technologies that can reduce women's actual workload, as well as help them to increase cash income. For this to happen, there is a need to examine the potential for diversifying economic activities while providing energy for value addition activities.

The work carried out in Yarsha helped both community members and the research team to enhance their knowledge, skills, and awareness of RETs. For example, the women in Yarsha measured fuelwood with a spring balance for the first time, recognised the quantity of fuelwood consumed per meal, and viewed and understood different energy-saving devices like solar cookers, solar electricity, and peltric sets.

The survey was an excellent tool for identifying the problems, priorities, needs, and aspirations of the communities, and the presence of a research facilitator assisted communities in solving problems by themselves. The Energy Fair was a most effective way of marketing and promoting technologies in a short period. The research facilitator also played an important role in narrowing the gap between communities and the support or line agencies.

The Yarsha experience shows that, if properly planned, community-based energy planning and management activities need at least one year to have a substantial impact. For example, it took three months for women to take up the improved cooking stove programme seriously. Initially the process is slow but adoption accelerates if the technology is appropriate–and that is the key to success. Especially for the poorer sections of the community and women the technology must be user friendly, of immediate benefit, sustainable, and socially and environmentally appropriate.

Part Three

Climate, Water and Sediment Issues

1997-1998 Climate Analysis of the Xizhuang Watershed

Fan Lizhang, Lin Hai
Yunnan Climate Center, Kunming

Abstract

Data from the Ganwangkeng (Banqiao) meteorological station (25°13'N, 99°9'E), which is located in the middle of the Xizhuang watershed at 1955 masl, were used to provide an overall impression of the climatic conditions in the watershed, one of the five watersheds being investigated by PARDYP.

This paper provides climate information from June 3rd 1997 to December 31st 1998. Monitoring of rainfall and temperature started on June 3rd 1997, and of wind on September 3rd 1997. The strongest El-Nino of the 20th century occurred in 1997. This delayed the start of the rainy season and led to the lowest number of sunshine hours being recorded for July since records began. Precipitation was irregular, especially in July and September. The El-Nino phenomenon ended in the first half of 1998 but was followed by a strong La-Nina, which also influenced the climate of the watershed. The temperature and precipitation were higher than normal from January to April 1998. The 1998 rainy season began and ended as normal (May to mid October), but the temperatures were above and precipitation below average and the number of sunshine hours lower than average. In November and December temperatures were higher than normal and precipitation lower.

Meteorological Data

The 1997-1998 temperature, precipitation, sunshine, relative humidity, and evaporation data are summarised in Figures 48 to 52. Data are also shown for the Baoshan meteorological station, which is located in the Baoshan valley outside but near to the watershed and at lower altitude (approximately 30 km distance and 1600 masl).

Temperature

Yunnan Province is influenced by the South Asian monsoonal climate, which is characterised by distinct wet and dry seasons. In 1998, both the extreme minimum temperature (-0.7 °C), and the mean monthly minimum temperature (7°C) occurred in January. The extreme maximum temperature (28 °C) occurred in May, and the mean monthly maximum temperature (19 °C) in June (Figure 48).

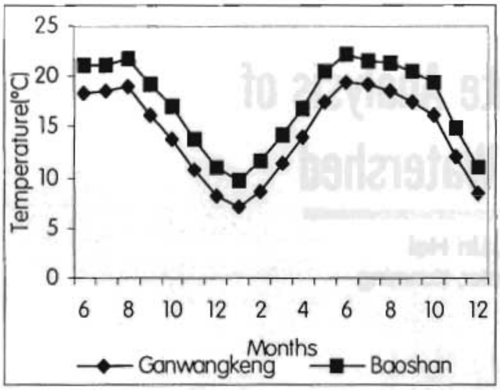

Figure 48: **Mean Monthly Temperatures from June 1997 to December 1998 (°C)**

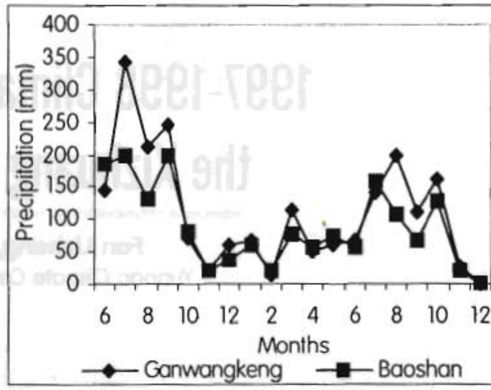

Figure 49: **Mean Monthly Precipitation from June 1997 to December 1998 (mm)**

Precipitation

The total precipitation in the second half of 1997 was 1096 mm and the total annual precipitation for 1998 was 1013 mm. Figure 49 shows the monthly precipitation from June 1997 to December 1998. In 1997, the rainy season in the watershed began on June 20th and ended on October 9th. The meteorological data for Baoshan indicate that the beginning of the rainy season was delayed by the influence of El-Nino.

In 1998, 22 per cent of the total annual precipitation fell in the period from January to April, and 70 per cent during the monsoon period from May-October. The 1998 rainy season began in late May and the most rain fell in July to October.

Sunshine

There were 940 hours of sunshine from June to December 1997 and 1,939 hours of sunshine in all of 1998.

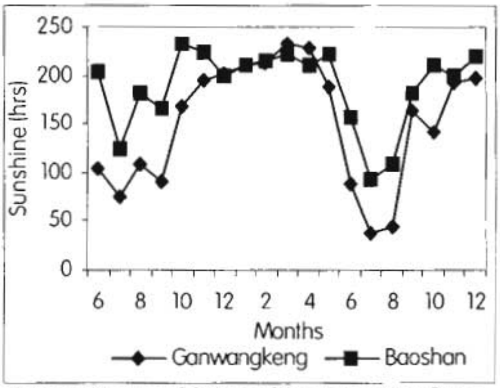

Figure 50: **Monthly Sunshine Duration from June 1997 to December 1998 (hrs)**

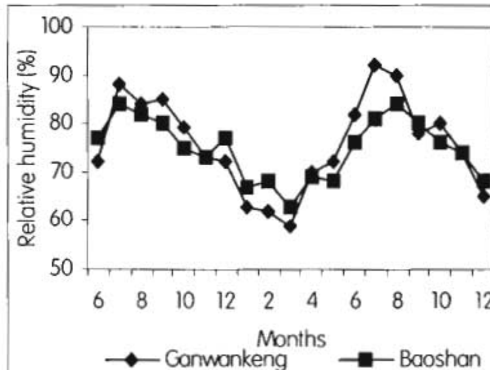

Figure 51: **Mean Monthly Relative Humidity from June 1997 to Dec. 1998 (%)**

Relative Humidity

The mean monthly relative humidity was low from January to April 1998; the lowest value was recorded in March (59%). The relative humidity increased during the monsoon reaching a peak of 92% in July. In December 1998, the mean monthly relative humidity was 65% (Figure 51).

Evaporation

In 1998, evaporation was highest in March and lowest in August. The sunshine hours and wind speed were somewhat higher than normal in March, resulting in a monthly evaporation rate of 147mm; in July the evaporation rate was 52mm.

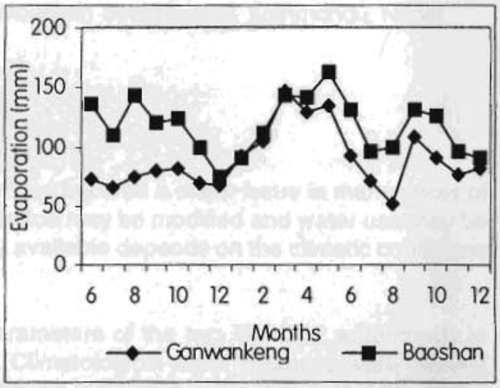

Figure 52: **Mean Monthly Evaporation from June 1997 to December 1998 (mm)**

Wind Direction and Speed

Wind observations began on September 3rd 1997. The maximum wind speed recorded (auto recording) was between 9 and 10 m/s. In 1998, the dominant wind direction in the dry season was SSW, in May (before the rainy season) and in September (towards the end of the rainy season), SW, and during the rainy season NE.

Comparison of Climatological Balances for the Jhikhu Khola and Yarsha Khola Watersheds, Nepal

Juerg Merz[1], Pradeep M. Dangol[2] and Madhav P. Dhakal[2]
[1] PARDYP/Department of Geography, University of Bern, Switzerland
[2] PARDYP/International Centre for Integrated Mountain Development, Kathmandu, Nepal

Abstract

Water availability for agricultural production has become a major issue in many areas of the middle mountains in Nepal. While water retention may be modified and water use may be regulated, the amount of water that is potentially available depends on the climatic conditions and cannot be changed.

This paper discusses the climatological parameters of the two PARDYP watersheds in Nepal, the Yarsha Khola and the Jhikhu Khola. Climatological water balances were derived and compared between the two watersheds. Water availability was shown to be a major problem for winter crops; water has become the major limiting factor for agricultural production. A distinct difference was identified between the two watersheds. Possible improvements to the current situation are suggested.

Introduction

Degradation of natural resources has been a concern in the Hindu Kush-Himalayas for many years. The People and Resource Dynamics Project (PARDYP) is trying to improve the understanding of the processes associated with this degradation (ICIMOD 1997).

Water is only one of the resources that is endangered. The agricultural and domestic demand for water is growing with intensifying agriculture and increasing population. However, the potential availability of water within the system of a watershed is limited and cannot be changed.

This study attempts to assess the potential water availability within the two PARDYP watersheds in Nepal, the Jhikhu Khola and Yarsha Khola watersheds (hereinafter referred to as Jhikhu and Yarsha), on the basis of the climatological parameters, rainfall and temperature. Only one year's data is available for the Yarsha watershed at present so that a comparison of the two watersheds is only possible for 1998. This is insufficient for conclusive remarks about the water availability, but indicates where further research needs to be focused.

The Study Area

The watersheds are both located in the middle mountains of Nepal. The Jhikhu watershed is situated about 45 km east of Kathmandu on the Arniko Highway (Figure 53) and covers 111.4 sq.km.The Yarsha watershed is located about 190 km east of Kathmandu on the Lamosangu-Jiri Road in Dholaka District and has an area of 53.4 sq.km. The two watersheds differ not only in their altitudinal range (Jhikhu watershed 800 to 2200 masl, Yarsha watershed 990 to 3030 masl) and size, but also in their physiography. The Jhikhu watershed is a main valley with a large flat valley bottom of alluvial origin, where the major land use is irrigated agriculture. Short and steep slopes confine it on the southern and northern sides. There are many pocket-like valleys on the flanks, which make the watershed very heterogeneous. The general aspect of the watershed is south-east. The Yarsha watershed has a general south-west aspect, and a south and north facing slope with a small middle ridge in between. There is no extensive flat valley bottom of alluvial origin and irrigated areas are limited, especially in comparison with the Jhikhu watershed. The Yarsha watershed appears more homogenous than the Jhikhu watershed.

A dense network of meteorological stations has been established in both watersheds (Figure 53). A total of 10 stations in the Jhikhu Khola and 11 stations in the Yarsha Khola are used for climatological measurements, in particular rainfall and temperature. The characteristics of the stations are given in Table 55. Missing station numbers indicate hydrological stations and erosion plots. In the Yarsha watershed a good spatial coverage was chosen with the aim of obtaining data sets with good horizontal and vertical distribution. The meteorological measurements in the Jhikhu watershed focus on some sub-catchments of interest.

Measurements were started in the Jhikhu watershed in 1992, but in the Yarsha watershed only in 1997. Thus the first complete year data set for the Yarsha watershed is that for 1998 and the two watersheds can only be compared on the basis of the data for that year.

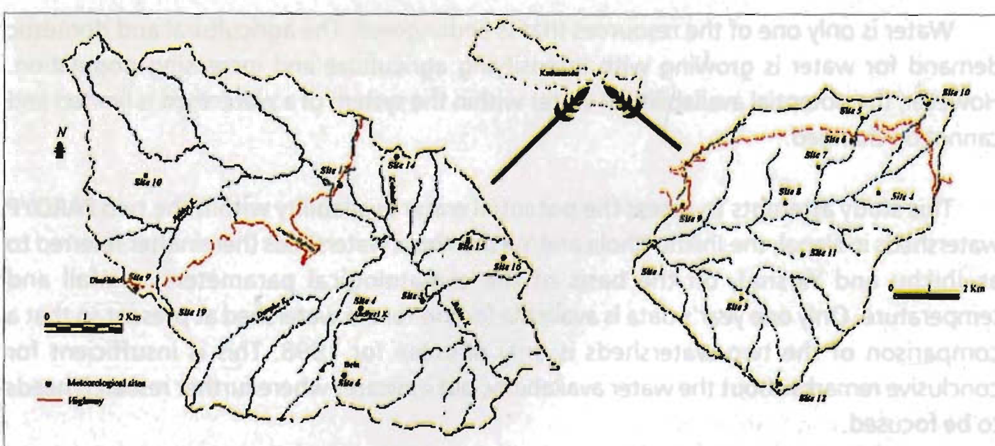

Figure 53: **Location and Measurement Networks of the Jhikhu and Yarsha Khola Watersheds**

Table 55: **Station Characteristics of Meteorological Stations in the Jhikhu and Yarsha Khola Watersheds**

Station No.	Station Name	Elevation (m)	Parameters Measured
Jhikhu Khola			
3	Acharyatol -Baluwa	830	RA, AT, ST
4	Baghakhor	940	RA, RI
6	Bela	1,280	RA, RI, AT, ST
9	Dhulikhel	1,560	RA, AT
10	Bajrapare	1,100	RA
12	Tamaghat	850	RA, RI ,AT, ST
14	Kubindegaun	880	RA ,RI
15	Bhimsensthan	880	RA, RI, AT, ST
16	Bhetwalthok	1,200	RA, RI, AT, ST
19	Bhattidanda	1,640	RA, AT, ST
Yarsha Khola			
1	Main Hydro Station	1,005	RA, RI, AT, ST
3	Gairimudi	1,530	RA, RI, AT, ST, H
4	Yarsha Forest Site	1,990	RA, RI, AT, ST
5	Thulachaur	2,300	RA, RI, AT, ST, H
6	Jyamire	1,950	RA, RI, AT, ST
7	Bagar (NARC)	1,690	RA, RI, AT, ST, WS, WD, N, H
8	Nimkot	1,420	RA, RI, AT, ST
9	Namdu	1,400	RA, RI, AT, ST, H
10	Thuloban	2,640	RA, RI, AT, ST
11	Mrige	1,610	RA, RI, AT, ST
12	Pokhari	2,260	RA, RI, AT,

Note:

RA	Rainfall amount	WS	Wind speed
RI	Rainfall intensity	WD	Wind direction
AT	Air temperature	N	Net radiation
ST	Soil temperature	H	Relative humidity

Both watersheds are represented by a main meteorological station: at Bagar (NARC) for Yarsha and at Tamaghat (Horticultural Farm) for Jhikhu. A variety of parameters are monitored at these stations. At normal stations, the rainfall amount, rainfall intensity, and air and soil temperatures are generally measured on a regular basis. Rainfall totals are measured in both watersheds with ordinary standard rain gauges of 8" diameter. Local readers read them daily at 08:45. The Department of Hydrology and Meteorology of Nepal (DHM) is using the same type of rain gauge and reads at the same time. Rainfall intensity information is derived from tipping bucket measurements. The tipping buckets are also of 8" diameter and can therefore be cross-checked with the data from the standard rain gauges. Two methods of recording are employed: some stations record rainfall by event, which allows the calculation of any intensity required; others record at regular time intervals of 2 minutes, which allows the calculation of two minute intensities. Both ordinary and tipping bucket rain gauges are installed with the receiving orifice 1 m above ground level.

Temperature is measured with thermistors (temperature loggers) which are installed between 1.25 and 1.5m above ground level in a Stevenson screen.

Potential evapotranspiration (PET) was calculated by the Thornthwaite method as proposed by ICIMOD (1996). The method is explained in detail in Thornthwaite *et al*. (1955).

It requires mean monthly temperatures in order to determine tabulated monthly heat indices. These values are summed to give yearly heat indices. Unadjusted PET can be determined with the help of a value table. With information on the location (latitude) of the site, the PET can be adjusted to local conditions.

More recent installations include piche evaporimeters in the Yarsha watershed, and Chinese made evaporation pans and a piche evaporimeter at the main meteorological station in the Jhikhu watershed. In the future it will be possible to compare the results of the indirect method of determining evaporation with actual field measured evaporation.

Monthly climatological balances were calculated from the recorded rainfall, evapotranspiration, and field capacity values following the book-keeping procedure (Thornthwaite *et al.* 1955). Monthly field capacity values were taken from those reported in Upadhyay (1985), from Jiri (250 mm) for the Yarsha watershed balances and from Kathmandu (200 mm) for the Jhikhu watershed balances.

Calculation of the climatological water balance with this method is a first approximation of the conditions found in the two watersheds. Further investigation and verification of some of the parameters (e.g., field capacity, PET) are still needed.

Climatological Balances and Parameters in the Yarsha Khola Watershed

Although there are no long-term data available from within the Yarsha watershed, the DHM maintains stations in Jiri and Charikot, both of which are close by. The Yarsha meteorological main station at Bagar is considered to be representative for the whole catchment (Doppmann 1998). The annual mean rainfall at Bagar in 1998 is shown in Figure 54 together with the values for Jiri and Charikot from 1987 to 1994 (DHM 1992;

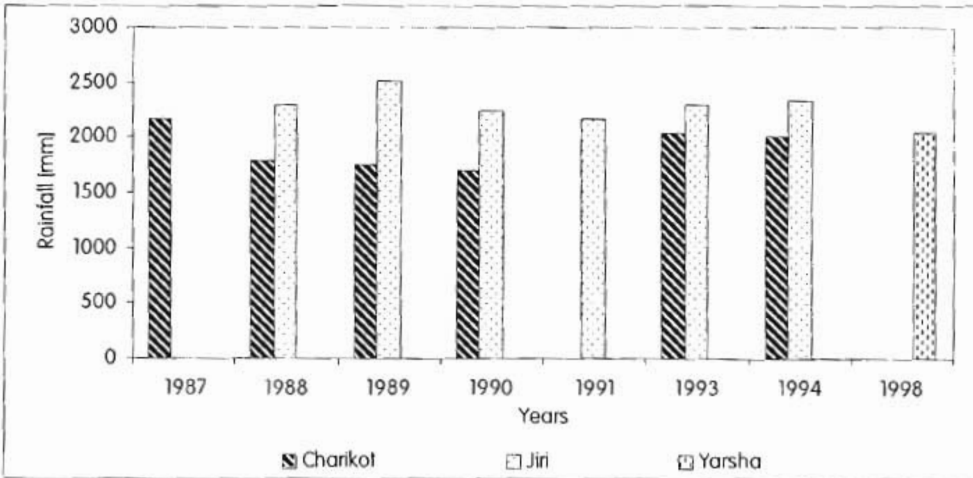

Figure 54: **Annual Mean Rainfall at Jiri and Charikot from 1987 to 1994 in Comparison with Annual Rainfall 1998 at Bagar (Data Source for Jiri and Charikot: DHM, 1992; DHM 1997a)**

DHM 1997a). Data for 1995 onwards are not yet available from DHM as they are still being checked. The overall mean annual rainfall at Jiri (2003 masl) from 1987 to 1994 was 2310 mm and at Charikot (1960 masl) 1909 mm. The annual mean rainfall for the whole region is 1800 to 2000 mm (ICIMOD 1996). The annual mean rainfall at Bagar (1690 masl) in 1998 was 2048 mm. The results indicate that 1998 was not an exceptional year in terms of annual mean rainfall although this cannot be finally confirmed until the 1998 data for Jiri and Charikot are available.

The spatial variability of rainfall within the watershed is large (Figure 55). In 1998, the annual rainfall varied from from 1600 mm in the lower parts of the watershed, to 3300 mm in the upper parts. The altitudinal gradient varied from 114 mm rainfall/100m vertical distance on an annual basis to 97mm/100m during the monsoon. Similarly, the number of events increased with increasing altitude. An event was taken to be a total rainfall of more than 3 mm with less than two hours break between each recording (definition from Carver 1997). In Thulachaur (2300 masl), the highest station with a whole year rainfall record in the watershed, a total of 132 events were recorded for 1998; whereas the number of events at the lowest station, the Main Hydro Station (1005 masl), was only 52 (Table 55). These events mainly occurred during the monsoon (June-September; Hofer 1998), which reflects the high temporal variability in the annual rainfall. Eighty per cent of the total annual rainfall at all stations fell during the monsoon and an average of 16 per cent during the pre-monsoon season (March to May). The rest was distributed in the post-monsoon and winter periods. Thus there were two distinct seasons: wet and dry.

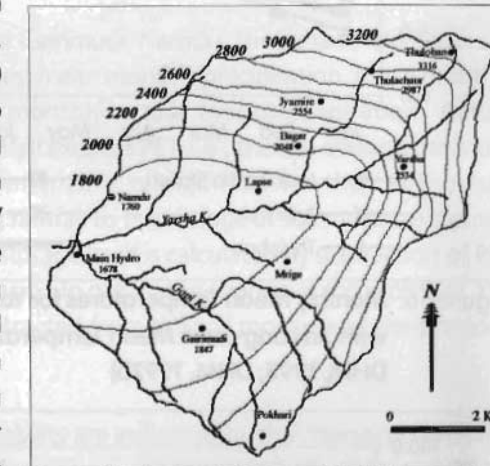

Figure 55: **Isohyetal Map of 1998 Annual Rainfall (mm) for the Yarsha Khola Watershed, 1998**

The Thornthwaite PET calculation is based on temperature, as explained above, and for 1998 this was the only parameter available to calculate the PET for several stations within the watershed. The variation in temperature over the year is shown in Figure 56. There was an altitude gradient of 0.65°C per 100m. Overall the mean monthly temperature ranged from 5.2°C in January at Thulachaur, to 26.6°C at the Main Hydro Station in June. June was the hottest month at all the stations in the Yarsha watershed. The mean monthly temperature for June at Bagar was 22.3°C, which matches well with the temperature of 21 to 24°C given by ICIMOD (1996) for this region. The 1998 temperatures also showed a good match with the long-term mean temperature of Jiri (Figure 56).

The calculated graph of PET is shown in Figure 57. It looks similar to the temperature curve as the calculations were based on temperature. The peak PET at all stations was

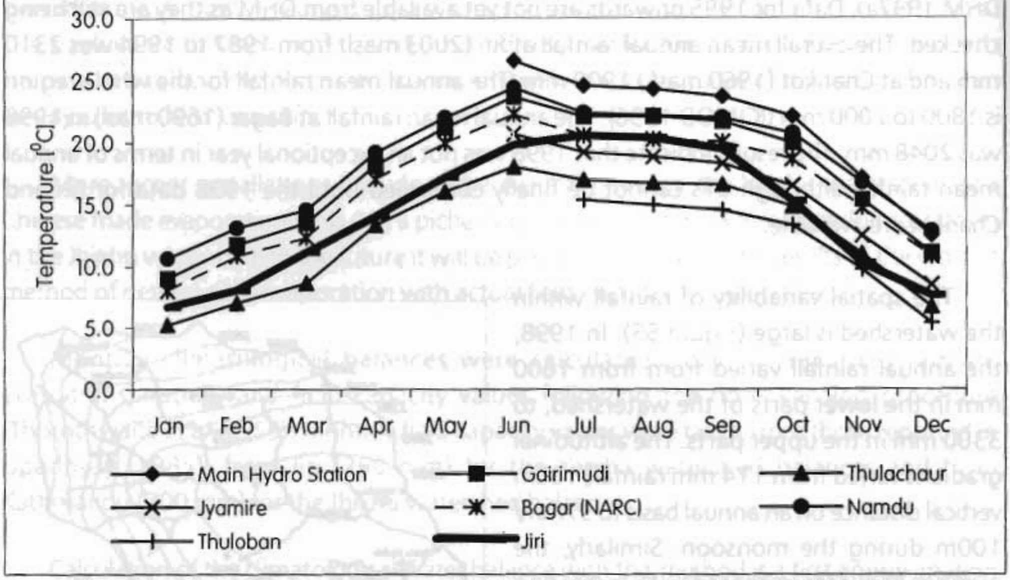

Figure 56: **Monthly Mean Temperatures for Yarsha Khola Watershed, 1998, in Comparison with Jiri Long-term Mean Temperature (1987 – 1994). (Data Sources for Jiri: DHM, 1995; DHM, 1997b)**

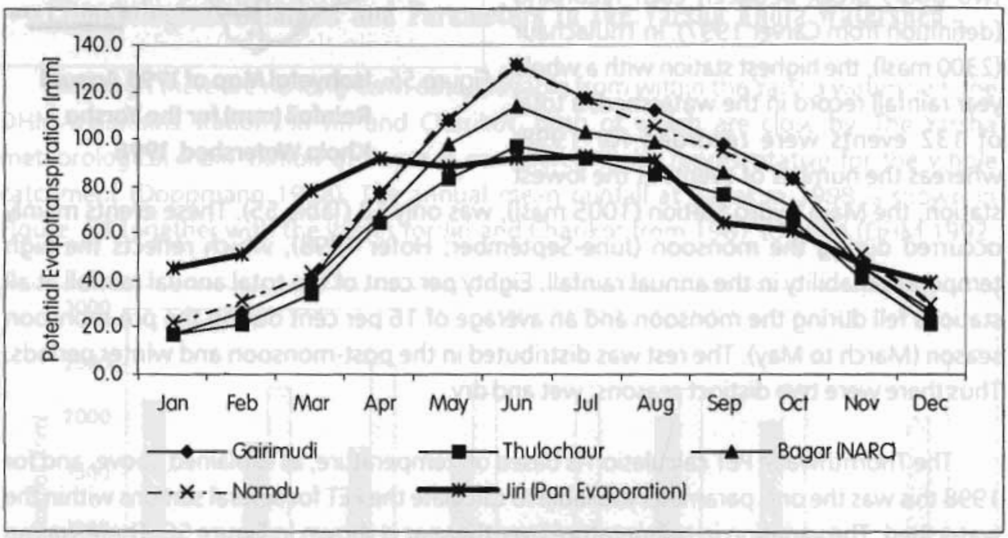

Figure 57: **Potential Evapotranspiration at Selected Stations in the Yarsha Kola Watershed 1998 in Comparison with Long-term PET Derived from Class A Pan Data for Jiri (Data Source for Jiri: DHM, 1995; DHM, 1997b)**

calculated to be in June, the hottest month of the year. The lowest PET was calculated to be in January with a rapid increase thereafter towards June. The calculated data for Bagar (NARC) were compared with the class A evaporation pan data for Jiri as a crosscheck (Figure 57). For this purpose, the class A pan data was converted to PET by applying a conversion factor of 0.8 (mid-summer), 0.7 (spring), and 0.6 (winter) (WECS).

The calculated values for Bagar and the measured values for Jiri agree fairly well for May to November; but during the winter and pre-monsoon months the PET appeared to be underestimated by the calculation method used. The low values during May and June in the Jiri data set were unexpected, however, as in the middle hills of Nepal, peak PET is normally expected during the May/June period. On the other hand, Thornthwaite's method is directly related to temperature, thus an overestimate during summer and an underestimate during winter is likely. In future, measured evaporation data will be compared directly with the calculated data .

The calculated climatological balances for Gairimudi, Namdu, Thulachaur, and Bagar are shown in Figure 6. The graphs show three lines: mean monthly precipitation, mean monthly potential evapotranspiration, and mean monthly actual evapotranspiration. Actual evapotranspiration is equal to PET when rainfall exceeds PET, i.e., there is enough moisture available to fulfill the atmospheric requirements. If rainfall is lower than PET, actual evapotranspiration is determined by adding rainfall to the change in soil moisture storage over the period of one month. Soil moisture storage itself is calculated by subtraction of PET from rainfall and with reference to field capacity. To obtain the change in soil moisture, the soil moisture of any particular month is subtracted from the soil moisture of the previous month.

Different stages of potential water availability are indicated by the intersections of the different graphs: water surplus, soil moisture recharge, soil moisture utilisation, and water deficiency (see legend to Figure 58). Soil moisture recharge occurs when rainfall exceeds the potential evapo-transpiration; this occurs mainly during the pre-monsoon and early monsoon. After full recharge of soil moisture, there is a water surplus during any subsequent times of excess rainfall . With the end of the monsoon, soil moisture utilisation and water deficiency begin. Water deficiency occurs when potential evapotranspiration exceeds soil moisture availability, i.e., the available soil moisture is fully utilised by high actual evapotranspiration.

The potential climatological water availability differs between different locations and at different times. Thulachaur, the highest station in the watershed for which a balance is available, only showed soil moisture utilisation during three months of 1998 (November, December, and January). In contrast, Namdu, representing lower watershed areas, faced water shortages during six months of the year (October to February and May). Gairimudi, the only station on a north-facing slope, also faced water shortages during five months of the year. The available soil moisture met the requirements of PET in all the calculated balances, which is indicated by the close or exact overlaying of the actual evapotranspiration and PET graphs. This shows that there are only minor periods of water deficiency within the Yarsha watershed. Soil moisture utilisation was most likely to occur during the winter months at all stations. Climatological water shortages (soil moisture utilisation and/or water deficiency) were most likely to occur during the post-monsoon and pre-monsoon periods at lower altitude stations.

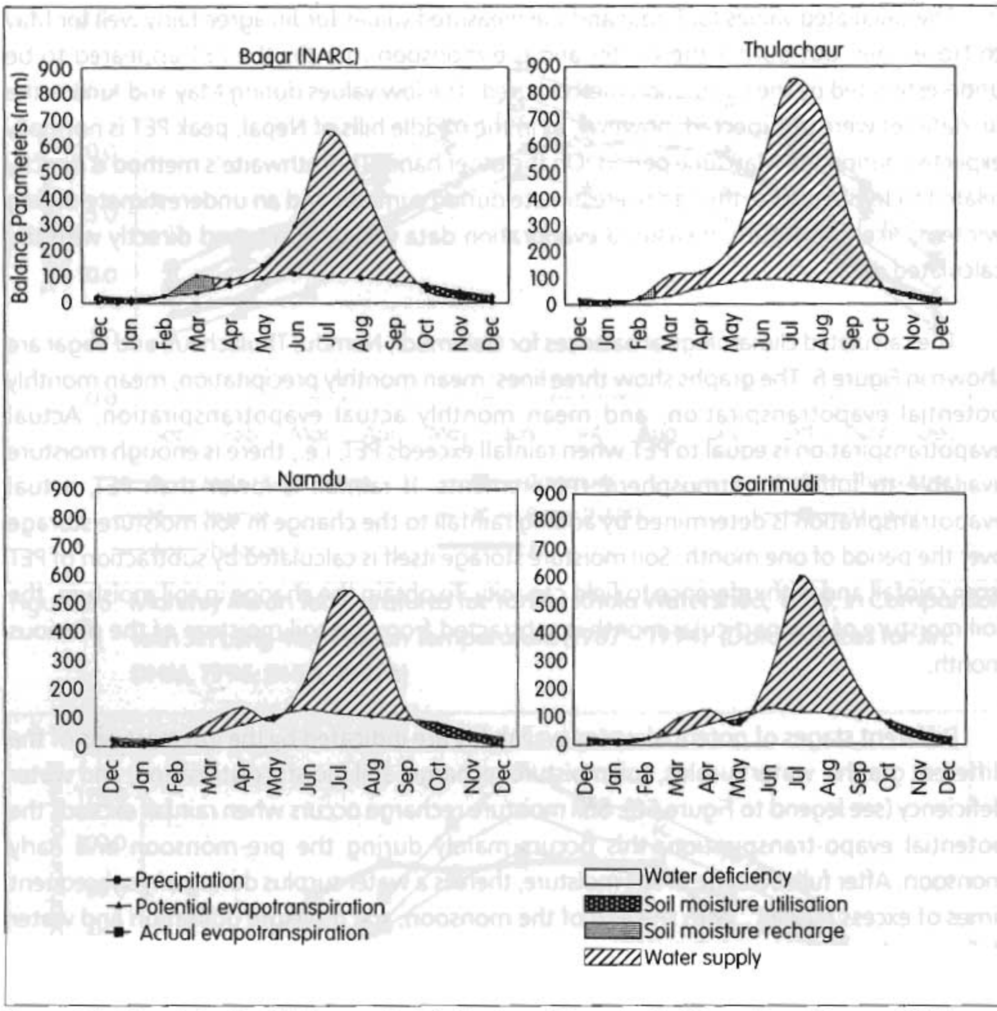

Figure 58: **Climatological Balances for Thulachaur, Namdu, Gairimudi and Bagar, 1998**

Climatological Balances and Parameters in the Jhikhu Khola Watershed

The station representative for the whole watershed is situated at Tamaghat (830 masl), which is part of the DHM meteorological network of Nepal. Data for this station since 1992 are available in the PARDYP database. The rainfall data for 1998 were compared with the data for 1992 to 1997 (Figure 59). The 1998 total of 1351 mm was somewhat higher than the long term mean of 1182 mm, and than the range of 1000–1200 mm given by ICIMOD (1996) for this region. The amount of rain in the 1998 pre-monsoon season, was more than double the long-term mean (297 mm in 1998 compared with 143 mm in the period 1992–1998) and this explains in part the excess in annual rainfall. The 1998 monsoon rainfall was also slightly higher than the long-term mean (990 mm in 1998 compared with 942 mm in the period 199–1998), but the winter of 1998 was exceptionally dry with less than half the average rain of other years.

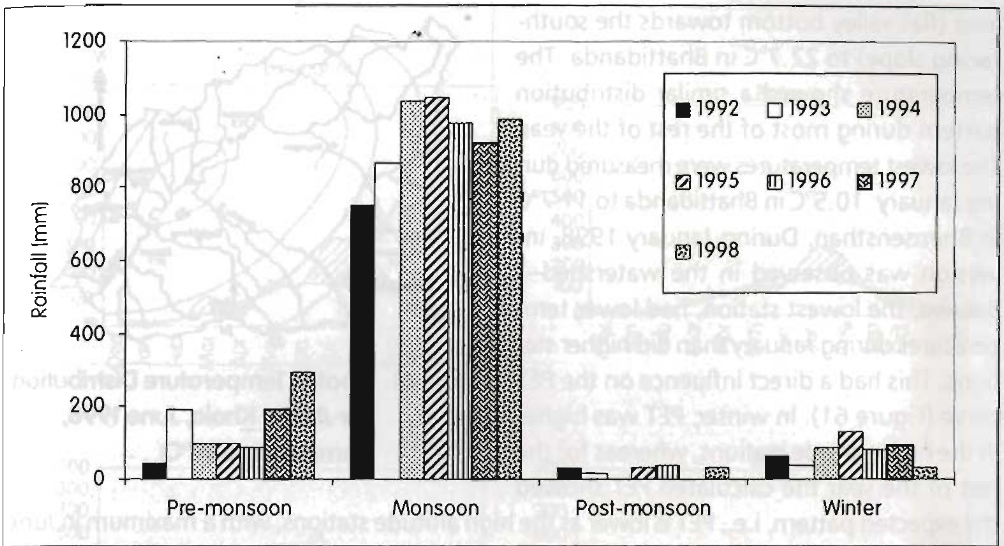

Figure 59: **Seasonal Rainfall at Tamaghat in 1992 - 1998**

The Jhikhu watershed is very heterogeneous, and with the existing monitoring network, it is difficult to assess the spatial distribution of rainfall within the watershed properly. The results of the best attempt are shown in Figure 60. In 1998, the rainfall varied from 1100 mm around the main hydrological station in the east of the watershed to more than 1700 mm in Bhattidanda and Dhulikhel. The valley bottom, where agricultural intensity is high, is the driest part of the watershed. It wasn't possible to measure changes in the number of events with altitude as there is no tipping bucket at Bhattidanda or Dhulikhel. In 1998, 81 events were measured at Tamaghat, the lowest station with a tipping bucket, and 82 in Bela.

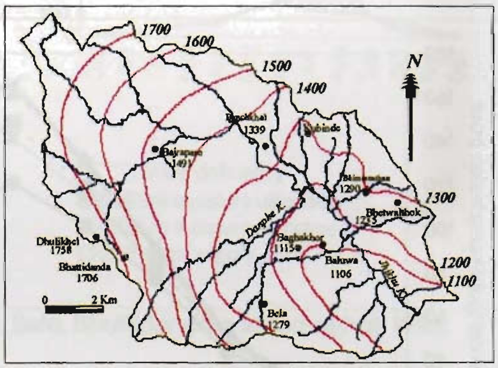

Figure 60: **Annual Rainfall Distribution in the Jhikhu Khola Watershed, 1998 (rainfall in mm)**

There was a high temporal variability in the rainfall amount. The monsoon rainfall is closely related to altitude and varied between 768 mm at the lowest meteorological station in Baluwa (69 % of the annual rainfall), to 1414 mm at Dhulikhel (80 % of the annual rainfall). On average, 74 per cent of the annual rainfall in Jhikhu fell during the monsoon in 1998, compared with a long-term mean of 80 per cent for the period 1992 to 1998. The pre-monsoon rainfall was particularly extensive in 1998; at Tamaghat 22 per cent of the annual rainfall fell during this season, compared with a long-term mean of 12 per cent.

The temperature distribution within the watershed during the hottest month, June, is shown for 1998 in Figure 61. The temperature varied from a mean of 27.7°C in the warmest area (flat valley bottom towards the south-facing slope) to 22.7°C in Bhattidanda. The temperature showed a similar distribution pattern during most of the rest of the year. The lowest temperatures were measured during January: 10.5°C in Bhattidanda to 11.7°C in Bhimsensthan. During January 1998, inversion was observed in the watershed—Baluwa, the lowest station, had lower temperatures during January than did higher stations. This had a direct influence on the PET curve (Figure 61). In winter, PET was higher in the high altitude stations, whereas for the rest of the year the calculated PET showed the expected pattern, i.e., PET is lower at the high altitude stations, with a maximum in June (165 mm at Bhimsensthan and Baluwa). The lowest PET values were calculated in January at Baluwa and Tamaghat.

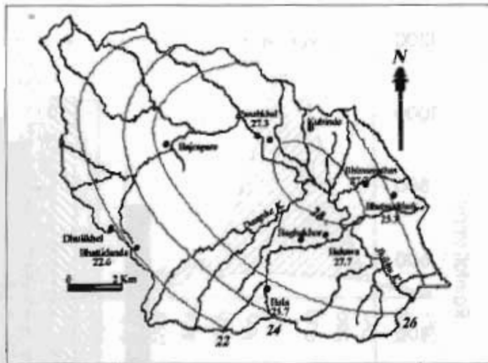

Figure 61: **Spatial Temperature Distribution for Jhikhu Khola, June 1998, (temperature in °C)**

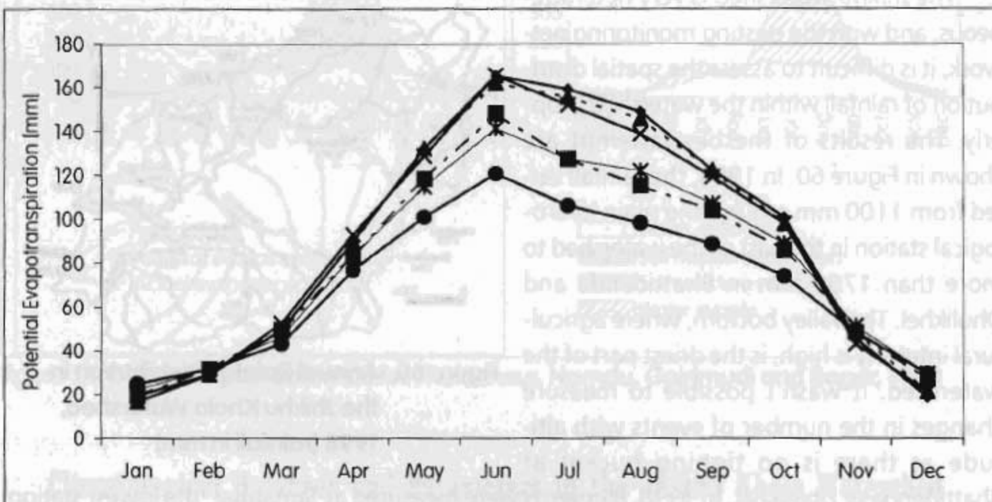

Figure 62: **Potential Evapotranspiration for Jhikhu Khola, 1998**

Climatological balances were calculated on the basis of rainfall and evapotranspiration and are shown for Baluwa, Bela, Bhattidanda, and Tamaghat in Figure 63. The comparatively low rainfall values associated with relatively high temperatures suggest that there are strong possibilities for water deficiency in many places in the Jhikhu watershed. In 1998, even the highest station situated at Bhattidanda was likely to have had six months of water deficiency or at least soil moisture utilisation. The lowest station in Baluwa faced

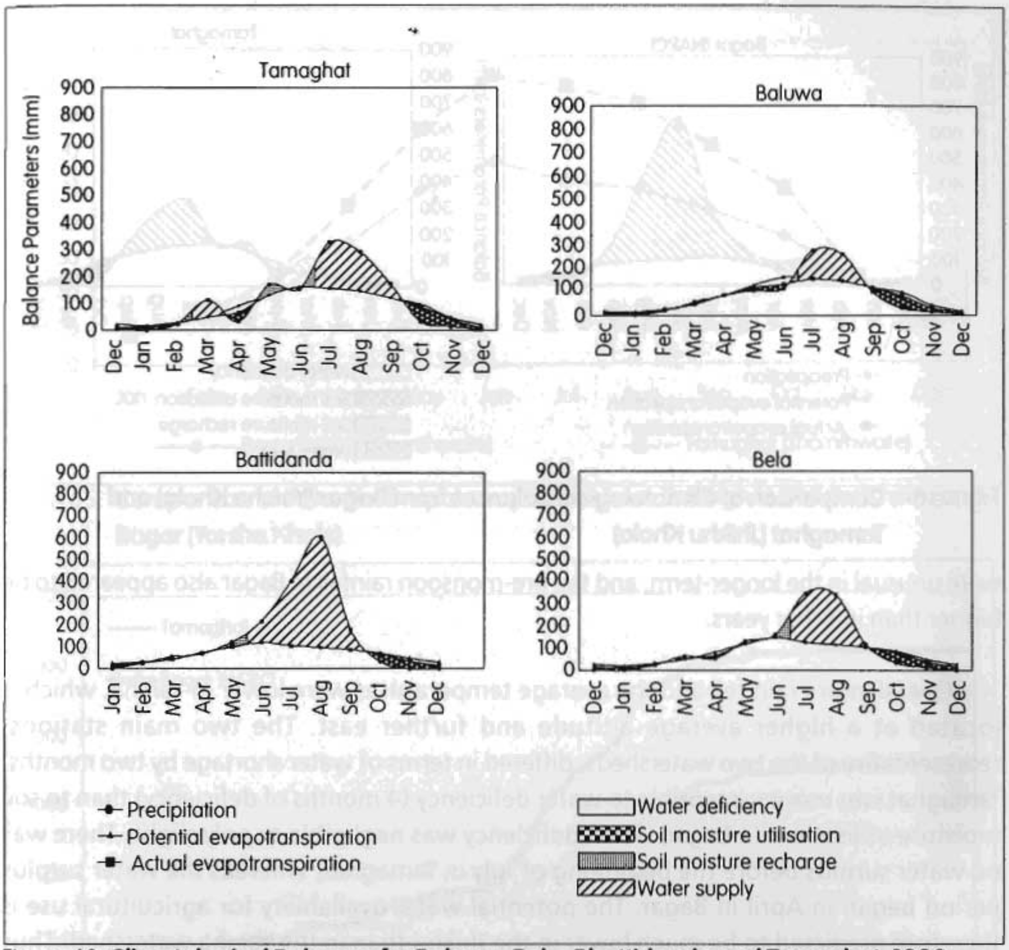

Figure 63: **Climatological Balances for Baluwa, Bela, Bhattidanda and Tamaghat, 1998**

water shortages for nine months of the year; with water deficiency for six of these nine months. Water shortage was recorded at all stations during the winter and post-monsoon periods, and during the pre-monsoon all stations were on the boundary between soil moisture recharge and soil moisture utilisation, i.e., the available rainfall was just or just not able to fulfil the requirements of PET.

Comparison Between the Yarsha Khola and Jhikhu Khola Watersheds

The climatological balances, calculated from rainfall and evapotranspiration data, provide an indication of potential water availability at different locations. Figure 64 shows the balances at the two main stations Tamaghat (Jhikhu) and Bagar (Yarsha) together to facilitate comparison (from Figures 58 and 63). The extent to which the 1998 climatological balances represent the long-term conditions in the watersheds can be assessed from the comparisons with the long-term data sets. 1998 does not appear to be an exceptional year, although the high pre-monsoon rainfall values in Tamaghat (Figure 59)

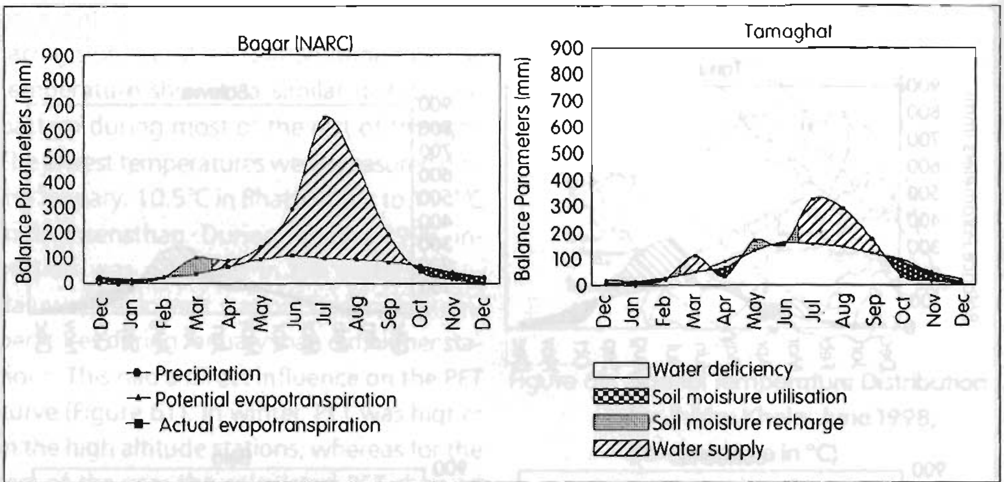

Figure 64: **Comparison of Climatological Balances from Bagar (Yarsha Khola) and Tamaghat (Jhikhu Khola)**

were unusual in the longer-term, and the pre-monsoon rainfall in Bagar also appeared to be higher than in other years.

Overall more rain fell and the average temperatures were lower in Yarsha, which is located at a higher average altitude and further east. The two main stations, representative of the two watersheds, differed in terms of water shortage by two months. Tamaghat was more susceptible to water deficiency (4 months of deficiency) than to soil moisture utilisation. In Bagar, water deficiency was negligible or only slight. There was no water surplus before the beginning of July in Tamaghat, whereas the water surplus period began in April in Bagar. The potential water availability for agricultural use is therefore predicted to be much lower in the Jhikhu than in the Yarsha watershed. Thus dependence on irrigation is likely to be much higher in Jhikhu, even for the highest station in the watershed, Bhattidanda, which faced a six month per annum water shortage. In contrast, Thulachaur in the Yarsha watershed only faced water deficiency during three winter months.

The months where the two stations differed most in terms of water availability were April and June, and the reason for this can be seen from Figures 65 and 66. While in late April, at the time of increasing evapotranspiration rainfall was already increasing in Bagar, rainfall and therefore adequate moisture did not start in Tamaghat until mid-May. The monsoon rainfall started somewhat later in Jhikhu than in Yarsha, which resulted in a one-month water deficiency in the watershed at the time that PET reached a peak (June).

A comparison of the water availability with the crop calendar reveals some interesting issues (Figure 67). Both main stations lie roughly on the boundary between zones of dominantly rainfed and dominantly irrigated agricultural land. Monsoon rice is planted in about June in the Jhikhu watershed which is still a time of soil moisture utilisation; thus a

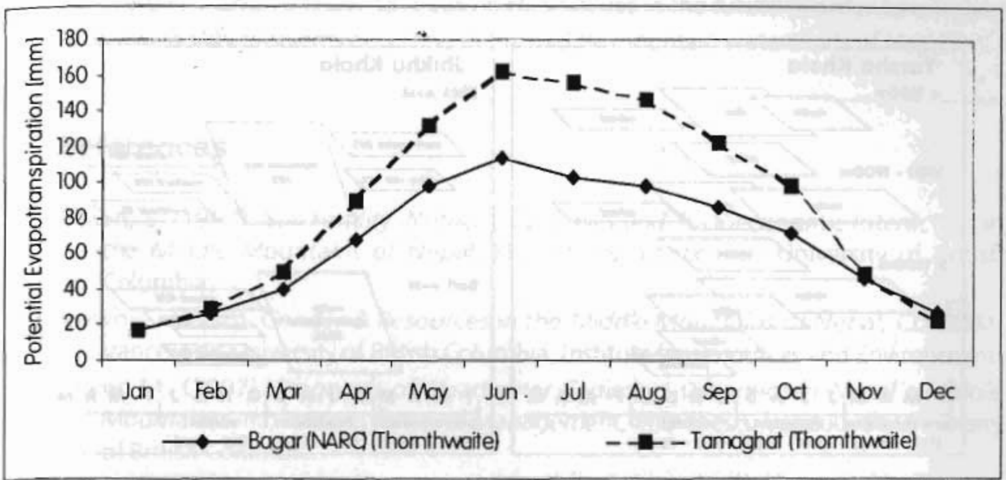

Figure 65: **Comparison of Potential Evapotranspiration from Tamaghat (Jhikhu Khola) and Bagar (Yarsha Khola)**

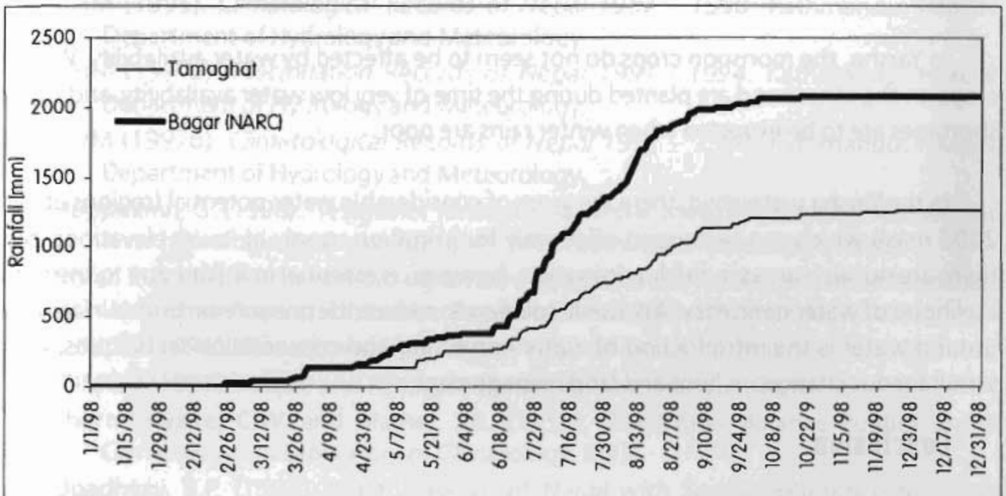

Figure 66: **Comparison of Daily Rainfall Sum Curves (Amount) from Tamaghat (Jhikhu Khola) and Bagar (Yarsha Khola)**

large input of irrigation water is needed. Even towards the end of the monsoon in September, water shortages can occur. This may affect the yield of the rice harvest as adequate moisture is needed at this time when the rice plants are at the flowering and milky stage.

On the rainfed land, maize is planted after the first monsoon rains, exactly at the time of high rainfall—the time of water surplus or adequate moisture. Maize, however, has high transpiration rates which may affect the water availability if soil moisture recharge is not ensured. Winter crops are planted in October when soil moisture utilisation has already begun; second winter crops are planted during water deficiency periods.

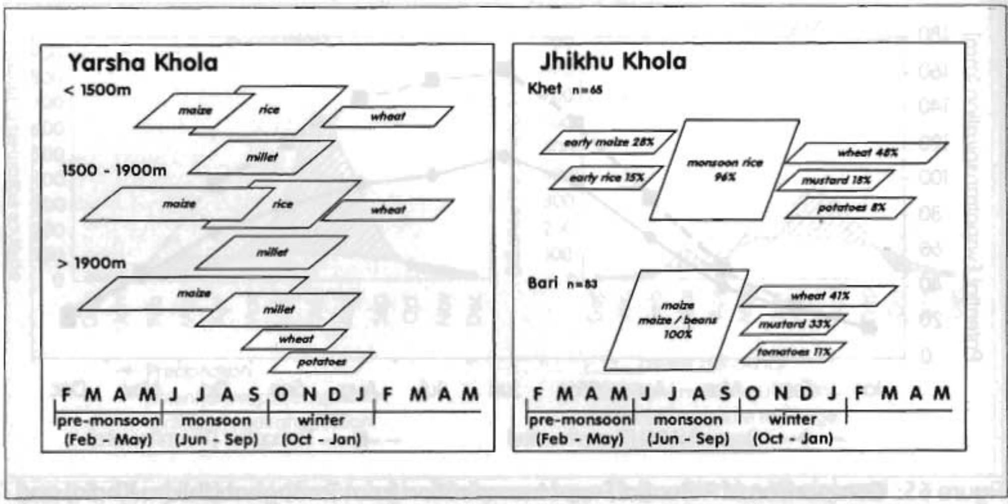

Figure 67: **Agricultural Calendars for the Yarsha Khola and Jhikhu Khola Watersheds**

In Yarsha, the monsoon crops do not seem to be affected by water availability. Winter crops on the other hand are planted during the time of very low water availability, and water shortages are to be expected when winter rains are poor.

In the Yarsha watershed, there are areas of considerable water potential (regions above 2000 masl) which can be tapped effectively for irrigation supply at lower elevations, but there are no such areas in Jhikhu. Irrigation, however, is essential in Jhikhu due to the high likelihood of water deficiency. A possible solution to reduce the pressure on both surface and ground water is the introduction of water harvesting and conservation techniques, with simultaneous changes in farm and land management.

Conclusion

The results show that there are areas and times of water shortage in both watersheds. In the Jhikhu watershed, most of the intensively used agricultural areas face acute water shortage during at least half the year, with a subsequent high demand for irrigation water. At the same time the availability of irrigation water is limited as there are no rainfall rich areas in Jhikhu watershed. Further pressure on water resources from population growth and the increasing trend towards agricultural intensification will lead to serious water shortages in the coming years. As climatological input of water cannot be changed, changes have to be made within the watershed. The possibilities suggested for changing water availability are:

- water harvesting technologies;
- water conservation technologies such as mulching and support of recharge; and
- changing land use practices and cropping patterns (agronomic interventions).

The PARDYP teams will have to focus on these issues in the future in order to mitigate the water availability problems occurring in the middle mountain watersheds of Nepal.

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Impact of Land Use on Generation of High Flows in the Yarsha Khola Watershed, Nepal

Juerg Merz[1], Bhawani S. Dongol[2], Rolf Weingartner[1], Gopal Nakarmi[2]
[1] PARDYP/Department of Geography, University of Bern, Switzerland
[2] PARDYP/International Centre for Integrated Mountain Development, Kathmandu, Nepal

Abstract

Flood generation has been the focus of discussions in the Hindu Kush-Himalayan region for decades. There are still differences in opinion about whether the land use practices of local farmers are responsible for downstream flooding. The present paper discusses the differences in stream flow generation from lands put to different use, in particular grazing and rainfed agricultural land. The results from sub catchments and erosion plots were compared during different flood events. The results suggest that grazing areas generally make a high contribution to runoff. During events with high rainfall intensities, all types of land use contribute to runoff. This suggests that under present conditions land management and land use has a limited influence on the generation of the highest flood events.

Introduction

Flooding and subsequent stream bank erosion are a severe problem in the foothills and adjacent plains areas of the Himalayas. Although different authors have stressed the importance of the farming practices of Himalayan farmers in the generation of flood events, opinions about their importance in this process differ widely.

This paper is concerned with the generation of high flow events at the watershed scale. Investigation of stream bank erosion, both active destruction like cutting and scoring and deposition within the watershed, is planned for the future. The contribution from different spatial levels (sub-catchments and plots) was determined and compared with the flow events at the main hydrological station. It is of interest to determine to what extent interventions at plot level are successful in preventing flooding. The question of the influence of different land use was addressed and thus the influence of different farming practices investigated.

The Study Area

The Yarsha Khola watershed covers 53.4 sq.km. and is located about 190 km east of Kathmandu on the Lamosangu-Jiri Road in Dolakha District. A network of meteorological and hydrological stations was established within the watershed during 1997 (Figure 68).

The network was set up according to nested approach principles as described in detail in Hofer (1998). For the purposes of this study, the watershed was divided into two sub-catchments, one predominantly on the south facing slope, referred to as the Yarsha Khola sub-catchment, and the other on the north-facing slope, the Gopi Khola sub-catchment. Smaller sub-catchments within these two sub-catchments, with different land use and cover, were monitored. Table 56 shows the key characteristics of these sub-catchments. Erosion plots, each monitoring 100 sq.m. of grazing land or rainfed agricultural land, were established within some of the smaller sub-catchments. The important physical aspects of the Yarsha Khola erosion plots are summarised in Table 57.

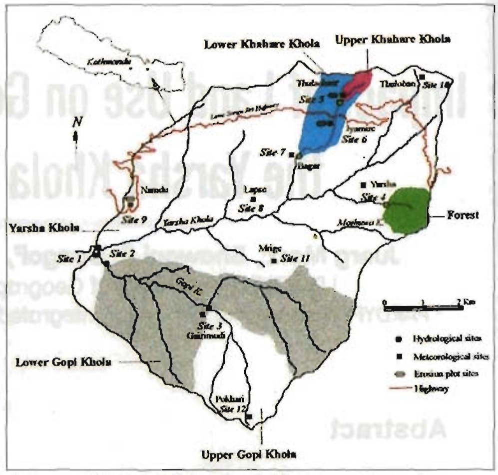

Figure 68: **Location and Measurement Network of Yarsha Khola Watershed**

For reasons of data availability, the present study focused on the hydrological stations along the Khahare Khola (Thulachaur, site 5, and Bagar, site 7), along the Gopi Khola (Gopi

Table 56: **Characteristics of the Yarsha Khola Watershed and the Monitored Sub-catchments**

Site No.	Catchment (Site Name)	Catchment Size (sq.km.)	Altitude (masl)	Land Cover (%)	
1	Yarsha Khola watershed (Main Hydro Station)	53.4	990-3050	Khet:13.9 Bari:37.4 Forest:31.5	Grass:5.7 Shrub:5.0 Other:6.5
	Yarsha Khola sub -catchment	36.0	990-3050	Khet:14.3 Bari:35.8 Forest:31.6	Grass:6.5 Shrub:5.1 Other:6.8
2	Gopi Khola sub-catchment (Gopi Khola)	17.4	1040-2495	Khet:13.3 Bari:40.8 Forest:31.4	Grass:3.9 Shrub:5.0 Other:5.7
5	Upper Khahare Khola sub-catchment (Thulachaur)	0.3	2280-2730	Khet:0 Bari:15.6 Forest:40.6	Grass:3.1 Shrub:25.0 Other:15.6
7	Lower Khahare Khola sub-catchment (Bagar)	2.1	1740-2730	Khet:0 Bari:50.5 Forest:14.4	Grass:10.1 Shrub:20.2 Other:4.8

Note: *Khet* = irrigated agricultural land *Bari* = rainfed agricultural land

Table 57: **Characteristics of Erosion Plots in the Yarsha Khola Watershed**

Site No.	Site Name	Land Cover	Soil Type	General Slope (deg)
5	Thulachaur	Grass/shrub land	Dark brown sandy loam	19.1
6	Jyamire	Terrace cultivation	Non red sandy loam	17
9a	Namdu	Terrace cultivation	Red loam	17.5
9b	Namdu	Grassland/fallow	Red sandy loam	17.5

Khola, Site 2), and at the main hydrological station (site 1)—see Figure 68. Sites 4 (Forest) and 3 (Gairimudi) were upgraded during 1998 so that when this study was done there was no complete and reliable data set available for either site. The rainfall data were taken from the sites in the relevant sub-catchments (Gairimudi (site 3; pure rainfall station), Thulachaur (site 5), and Bagar (site 7)), and the meteorological stations close to the erosion plots (Jyamire (site 6), and Namdu (site 9)).

Discharges were determined indirectly by measuring the water level and calculating the discharge using a rating curve. At the main station, the water level is measured digitally by means of a pressure transducer and logger (a Kern FL-2) which records values at five minute intervals during the monsoon (June to September) and at 15 minute intervals during the rest of the year. The other stations are equipped with a hydrograph floater (Ott R-16) that delivers analogue data. The analogue data is then digitalized on a 30 min interval basis for the monsoon season, and on a 60 minute basis during the rest of the year. Readings from the equipment are cross-checked with daily readings from staff gauges by local readers. The discharge used to establish the rating curves was measured using the dilution method. Uranin was used as a tracer at sites 1 and 2, a salt tracer technique was employed at the other stations. The discharge of the Yarsha Khola sub-catchment was determined by subtracting the discharge at the Gopi Khola station from the discharge measured at the main hydrological station.

The rainfall data was derived from 8" diameter tipping buckets with a 0.2mm capacity per tip. Each event of ≥0.2mm is recorded on a HOBO logger. This data was cross-checked with the data from ordinary daily 8" diameter storage rain gauges.

Hydrological Conditions During the Period of Investigation – the 1997 and 1998 Monsoons

More than 80 per cent of the annual rainfall in 1998 fell during the monsoon season (Merz *et al.* 1999). Major high flow events with subsequent stream bank erosion are only expected during this season. Figure 69 shows the daily discharge hydrographs for the two monsoon seasons 1997 and 1998 at the main hydrological station.

The hydrographs of daily discharge at the main hydrological station show only a slightly different picture for the two years. For example, the onset of monsoon discharge was earlier in 1998, beginning in late June to early July, whereas in 1997 the monsoon only resulted in higher discharges in early to mid July. However, the mean discharge of 5.07 cu.m/s in 1997 was slightly higher than that of 4.75 cu.m/s in 1998 (Figure 69). The discharge in 1998 was more homogenous. The minimum discharge during the study period was lower in 1997 than in1998 (0.69 cu.m/s compared to 1.94 cu.m/s) and the maximum discharge higher (16.69 cu.m/s compared to 13.25 cu.m/s). This resulted from the later onset of the monsoon in 1997, and the impact of the 16th and 17th July 1997 when there was an exceptionally big event. The maximum of that event was 56 cu.m/s (Doppmann 1998; corrected value). In

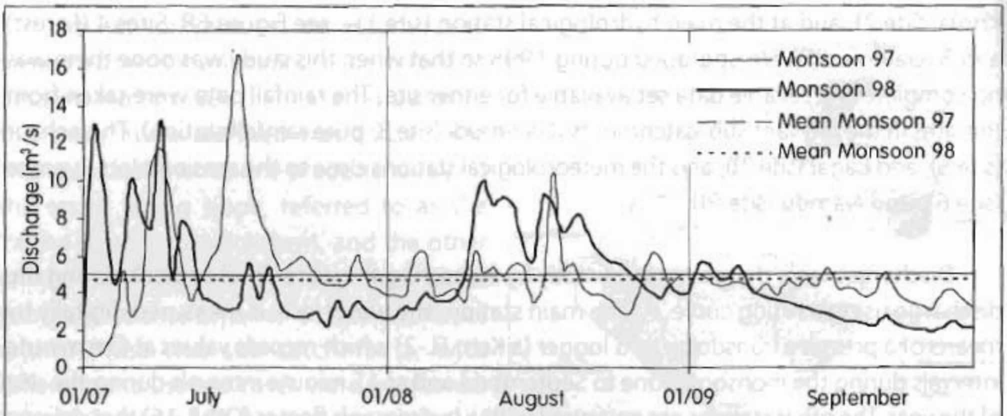

Figure 69: **Daily Discharge Hydrographs for the Monsoon Seasons 1997 and 1998 at the Main Hydrological Station, Yarsha Khola Watershed**

comparison, the highest peak discharge in 1998 was only 28.46 cu.m/s. In both years, the main events happened in early to mid July and mid August with a period of small events in between. September was calm in both years but during the 1997 monsoon the base flow was sustained during the month, whereas in 1998 it fell to post-monsoon flow immediately after the first week of September.

The daily discharge contributions of different sub-catchments to the total discharge at the main hydrological station are shown in Table 58.

The contribution of each sub-catchment depends mainly upon rainfall input. The Gopi Khola sub-catchment receives less rainfall proportionately than the Yarsha Khola sub-catchment, and its contribution to the total output of the watershed was lower than might be expected from the size of the catchment. However, the contributions of the Lower Khahare

Table 58: **Contribution of Different Sub-catchments to Areal Rainfall and Total Discharge of the Yarsha Khola Watershed, the Yarsha Khola Sub-catchment, and the Lower Khahare Khola Sub-catchment; Monsoons 1997 and 1998**

	Yarsha Khola Watershed				Yarsha Khola Sub-catchment				L. Khahare Khola sub-catchment			
	Area	Rain	D97	D98	Area	Rain	D97	D98	Area	Rain	D97	D98
Yarsha Khola sub-catchment	67	80	79	70	–	–	–	–	–	–	–	–
Gopi Khola sub-catchment	33	20	21	30	–	–	–	–	–	–	–	–
L. Khahare Khola sub-catchment	4	5	7	6	6	7	9	9	–	–	–	–
U. Khahare Khola sub-catchment	0.6	1	1	2	1	1	2	2	15	17	21	29

Rain: Average value for monsoons 1997 and 1998 according to Doppmann (1998)
D97: discharge contribution in 1997; D98: discharge contribution in 1998

Khola and the Upper Khahare Khola were slightly bigger (trend) than expected from their area and rainfall input.

One possible reason for these differences could be the different response of the sub-catchments to rainfall events, possibly as the result of different land cover conditions. The main difference between the different sub-catchments is the proportion of land in each under grassland, shrubland, and 'other' land use categories (Table 56). In the Upper Khahare Khola sub-catchment, 43.7 per cent of the land is in these land cover classes, and in the Lower Khahare Khola, 35.1 per cent, compared with 18.4 per cent in the Yarsha Khola sub-catchment as a whole and 14.6 per cent in the Gopi Khola sub-catchment. In addition, the fairly extensive forest in the Upper Khahare Khola sub-catchment is of very low quality and partially degraded and overused. The more than proportional contribution, in terms of both rainfall and area, of the Upper Khahare Khola sub-catchment to the flow of the Lower Khahare Khola measured at Bagar is therefore not surprising. Overall, the water retention capacity of the Lower and the Upper Khahare sub-catchments appeared to be lower than in the other sub-catchments, as indicated by the higher percentage of discharge originating from the two sub-catchments in comparison with the other sub-catchments.

High Flow Events at the Main Hydrological Station

The contribution of the different sub-catchments to total discharge was calculated on a long-term basis. We also investigated whether the same holds true for short-term periods or single events. Tipping bucket rainfall data was only available for 1998, so the generation of high flow events at the main station was only investigated for 1998. There was no big difference in daily discharge between the two monsoon seasons 1997 and 1998, however, so the results for the 1997 season are likely to have been similar. In order to understand the generation of high flow events at the main hydrological station, the five biggest events in 1998 in terms of peak event flow were selected and investigated at different spatial levels. Table 59 shows the characteristics of the selected events at the main hydrological station and Table 60 the rainfall characteristics of the same events across the watershed.

Four of the major events occurred in the period early to mid July and one in mid August. Most of the big events occurred during the night so that establishing the upper part of the rating curves was not easy.

Table 59: **Characteristics of Major Events in 1998 at the Main Hydrological Station, Yarsha Khola Watershed**

Date	Peak flow (cu.m/s)	Specific Discharge ($l/s*km^2$)	Mean discharge (cu.m/s)	Quick Flow (cu.m)	Time of Peak
09/07/98	28.46	530	12.75	25'518	4:00
02/07/98	27.63	520	12.73	28'785	2:00
03/07/98	18.73	350	10.69	21'512	0:00
17/08/98	18.11	340	9.11	13'061	4:00
05/07/98	17.51	330	9.26	25'198	16:00

Table 60: **Rainfall Characteristics of High Flow Events**

Date	Yarsha Khola												Gopi Khola		
	Thulachaur (5)			Jyamire (6)			Bagar (7)			Namdu (9)			Gairimudi (3)		
	P	D	I	P	D	I	P	D	I	P	D	I	P	D	I
09/07/98	43.8	477	5.5	69.0	540	7.7	73.2	640	6.9	66.2	687	4.2	88.2	889	6.0
02/07/98	82.4	496	10.0	81.2	603	8.1	85.8	435	11.8	35.8	378	5.7	41.0	392	6.3
03/07/98	89.0	480	11.1	57.0	482	7.1	54.4	450	7.3	26.2	371	4.2	47.6	331	8.6
17/08/98	49.6	938	3.1	48.2	708	4.1	51.5	780	4.0	18.0	78	4.5	29.2	734	2.4
05/07/98	47.2	289	9.8	58.6	1074	3.3	57.1	205	16.7	15.2	1229	0.7	13.0	58	13.4
Mean*	21.1	540	4.2	18.6	540	3.1	16.0	295	4.5	17.2	499	4.0	15.5	516	4.3
Max*	95.0	-	-	89.6	-	-	85.8	-	-	85.6	-	-	88.2	-	-

P = amount of rainfall during event (mm) D = duration of event (min) I = average intensity of event (mm/h)
* = mean and max for all events during 1998, calculated from whole year data set

The biggest event in 1998 was observed on July 9th. Peak discharge, the most important parameter for the assessment of stream bank erosion and flooding, reached a level of 28.46 cu.m/s. This represents a specific discharge of 530 l/s*km². The mean event discharge was in all cases between two and three times higher than the mean daily discharge of 4.75 cu.m/s during the whole period of the monsoon 1998.

Widespread rainfall over the whole area of the watershed is needed to generate a high flow event. During the first event there was high rainfall in both the major sub-catchments, Gopi Khola and Yarsha Khola. In the July 5th event, the smallest of the five, the amount of rainfall was only high in the upper areas of the Yarsha Khola sub-catchment, as was the case in the other three events, although the differences between the upper and lower areas in these events were smaller. In general, a high flow event is generated by rainfall events above the average amount and below the mean event duration . The average event intensity was above the average for the year in all the five biggest events in 1998.

The instantaneous intensity is also important. Both the maximum 60 minute rainfall intensity and the maximum 10 minute intensity at Bagar (main meteorological station) were high in all five events (Table 61). In the event of July 5th, rainfall amounts in the lower and southern parts of the watershed were comparatively low, but the maximum annual rainfall intensities were recorded for Bagar (main meteorological station).

In all cases, the rapid response of the main station to high rainfall events in the sub-catchments was visible. The rapid response is indicated by the low lag times between the maximum hourly rainfall intensity at Bagar and the peak flow (compare Tables 59 and 61). The peak flow was generally reached within 1 to 2 hours after the maximum 60 minute rainfall intensity was recorded. The lag times between peak flow and maximum 10 minute rainfall intensity of the events show a similar picture.

The discharge from the different sub catchments during the five events is shown graphically in Figure 70. The rapid response of the main station to the events can be seen clearly. Visual comparison shows no obvious similarities between the events. In all cases there was a contribution from both north and south facing slopes. The contribution of the Gopi Khola sub-catchment was generally quite low, except during the biggest event of July 9th. The Lower Khahare Khola measured at Bagar seemed to make a decisive contribution to

Table 61: Instantaneous Maximum Rainfall Intensities at Bagar (Main Meteorological Station), Yarsha Khola Watershed

Date	60min intensity		10min intensity	
	[mm/h]	Time	[mm/h]	Time
09/07/98	29.1	2:50 – 3:50	36.2	2:45 – 2:55
02/07/98	39.0	1:05 – 2:05	60.3	1:40 – 1:50
03/07/98	29.7	21:05 – 22:05	47.0	21:15 – 21:25
17/08/98	25.5	1:55 – 2:55	41.0	2:35 – 2:45
05/07/98	50.5	14:35 – 15:35	92.9	14:50 – 15:00
Annual Maximum	50.5	05/07/98	92.9	05/07/98

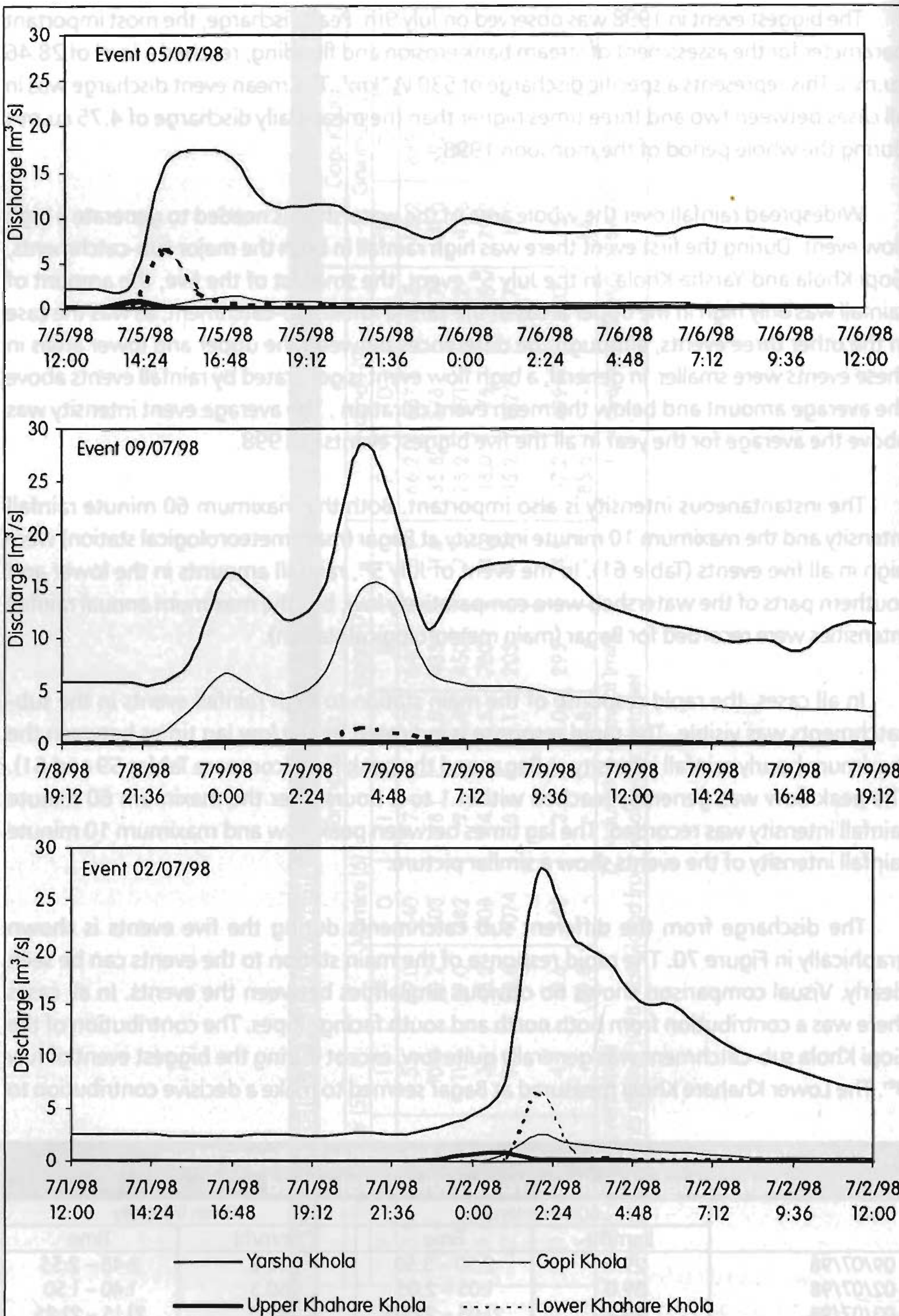

Figure 70: **The Five Biggest Events of 1998 at the Main Hydrological Station in Comparison with Events at Three Selected Sub-catchments, Yarsha Khola**

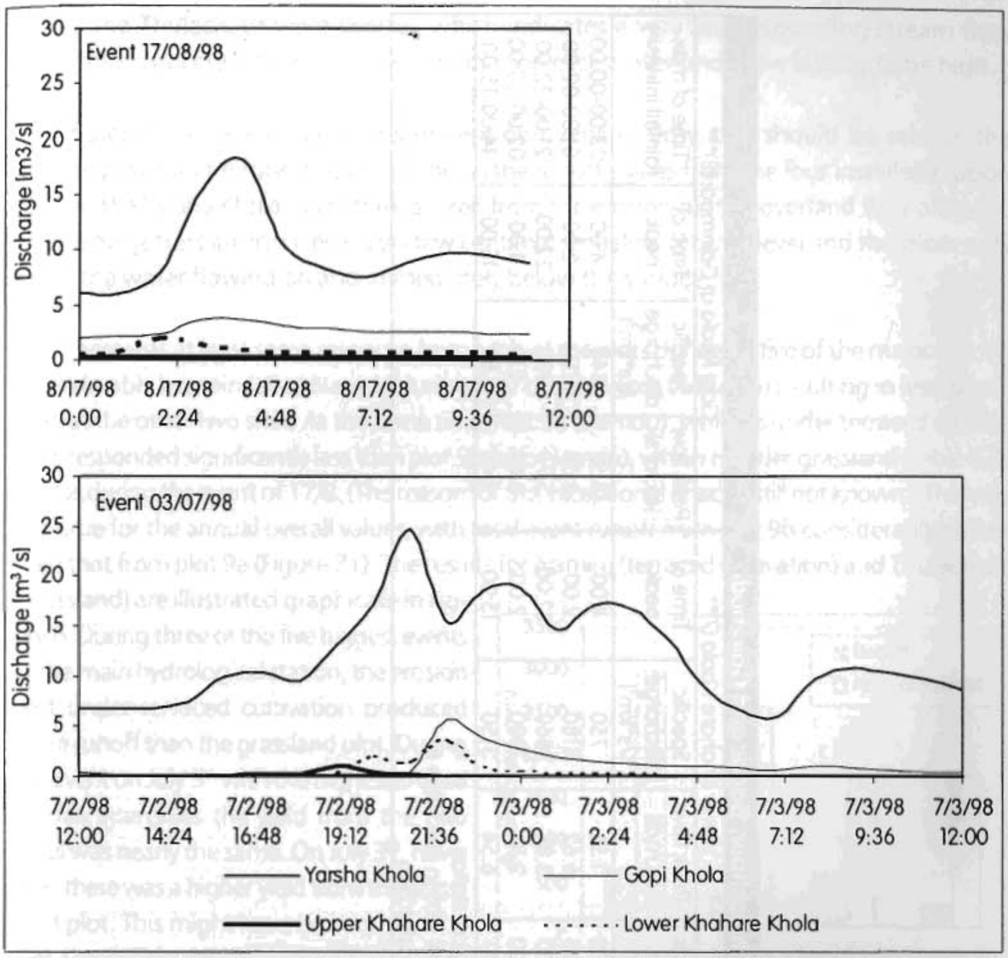

Figure 70: **The Five Biggest Events of 1998 at the Main Hydrological Station in Comparison with Events at Three Selected Sub-catchments, Yarsha Khola (cont'd)**

flood events, with a flood event generally measured at Bagar during flood events at the main hydrological station. The contribution of the Upper Khahare Khola measured at Thulachaur was similar, as also seen from the specific discharge values in Table 62. The specific discharge values (runoff per unit area) were very high in all events at Thulachaur and at Bagar, which indicates a high contribution of the two sub-catchments. The Gopi Khola sub-catchment did not yield any major runoff except during the first event.

The rapid response of the watershed to the rainfall events is indicated by the steep and fast change of the rising limb of the hydrograph. This rapid response indicates simultaneous rapid response to stream flow generation processes such as overland flow and/or subsurface storm flow. According to Anderson and Burt (1990), lag times of one to two hours indicate saturation overland flow at a watershed size of around 50 sq.km.

The lag times of the Gopi Khola showed a similar rapid response to maximum rainfall (Table 7, compare "Time of peak" and "Time of max rainfall intensity"). The lag times at

Table 62: **Characteristics of Selected Events at Sites Thulachaur, Bagar and Gairimudi**

Date	Upper Khahare Khola (5)*				Lower Khahare Khola (7)**			Gopi Khola at Gairimudi (3)***			
	Peak flow [cu.m/s]	Specific discharge [l/s*km^2]	Time of peak	Time of max rainfall intensity	Peak flow [cu.m/s]	Specific discharge [l/s*km^2]	Time of peak	Peak flow [cu.m/s]	Specific discharge [l/s*km^2]	Time of peak	Time of max rainfall intensity
09/07/98	0.14	440	4:00	03:00-04:00	1.56	750	4:00	14.53	840	4:00	23:00-00:00
02/07/98	0.86	2700	1:00	01:00-02:00	6.62	3180	2:00	2.59	150	2:00	01:00-02:00
03/07/98	1.02	3200	19:00	19:00-20:00	3.88	1860	22:00	5.76	330	22:00	21:00-22:00
17/08/98	0.22	700	2:00	02:00-03:00	2.10	1000	2:00	3.69	210	4:00	02:00-03:00
05/07/98	0.84	2630	14:00	14:00-15:00	6.54	3150	15:00	1.46	80	16:00	14:00-15:00

* Rainfall intensity from Thulachaur (Site 5) meteorological station

** For rainfall intensity from Bagar (Site 7) meteorological station see Table 61

*** Rainfall intensity from Gairimudi (Site 3) meteorological station

Bagar and Thulachaur were shorter, which indicates a very fast responding stream flow generation process. The influence of 'infiltration excess overland' flow is likely to be high.

If storm events are mainly dependent on overland flow, this should be seen in the erosion plot data for runoff. Table 63 shows the runoff values from the four installed erosion plots in the Yarsha Khola. Runoff measured from the erosion plots is overland flow only; the collection gutters are inserted only a few centimetres below ground level and therefore only catch the water flowing on and immediately below the surface.

There was at least some response from each of the plots during all five of the major events. Considerably less rain fell at Namdu during four of the events (Table 60) resulting in less runoff than at the other two sites. At the same time, Plot 9a (Namdu), which is under terraced cultivation, responded significantly less than plot 9b (also Namdu), which is under grassland (Table 62), except during the event of 17/8. (The reason for this exceptional effect is still not known.) This was also true for the annual overall values, with total event runoff from plot 9b considerably higher than that from plot 9a (Figure 71). The results for Jyamire (terraced cultivation) and Thulachaur (grassland) are illustrated graphically in Figure 6. During three of the five biggest events at the main hydrological station, the erosion plot under terraced cultivation produced more runoff than the grassland plot. During the event on July 5th with the highest annual rainfall intensities the yield from the two plots was nearly the same. On July 3rd, however, there was a higher yield from the grassland plot. This might have been due to the wet antecedent moisture conditions (from the big event on July 2nd). In contrast, the agricultural plot (Jyamire) reacted less overall than the grassland plot (Thulachaur) during events of average rainfall intensity and

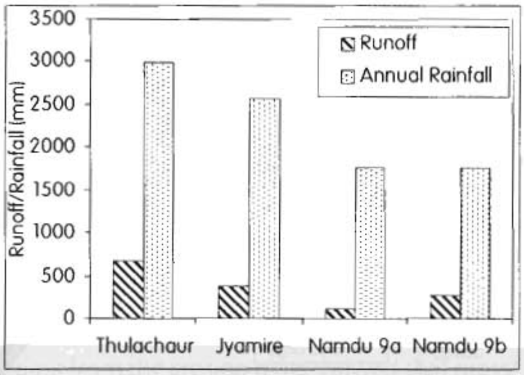

Figure 71: **Total Event Runoff for 1998 from Erosion Plots in Comparison with Total Rainfall Measured at the Sites, Yarsha Khola Watershed**

Table 63: **Runoff from Erosion Plots during the Five Biggest Events at the Main Hydrological Station, Yarsha Khola Watershed (runoff in cu.m/ha)**

	Lower Khahare Khola sub-catchment		Yarsha Khola sub-catchment	
	Thulachaur (5)	Jyamire (6)	Namdu (9a)	Namdu (9b)
	Grass/Shrub land	Terrace cultivation	Terrace cultivation	Grassland
09/07/98	127.7	264.6	27.4	269.8
02/07/98	113.7	281.8	11.0	54.6
03/07/98	295.9	196.4	8.4	53.9
17/08/98	137.6	184.0	88.9	86.6
05/07/98	296.1	278.7	1.6	4.4
Maximum*	297.4	288.5	103.1	269.8
Median*	14.7	6.2	4.9	9.1

* Maximum and median are calculated from the whole year data set, i.e., annual maximum and median

amount, as shown by the annual median value (Table 63) and annual total event runoff, both of which were higher for Thulachaur than for Jyamire (Figure 71).

Figure 72 shows the runoff values for all the events observed in 1998 at the agricultural plot (Jyamire) and the grassland plot (Thulachaur) in one graph. Events of more than 100 cu.m /ha runoff were investigated closely and connected with a line: a thick line when runoff from the agricultural land was higher than runoff from the grassland, and a thin line when runoff was higher from the grassland plot. The runoff from the two plots during the five biggest events at the Main Hydrological Station is shown in Figure 73.

During most of the events (including those below 100 cu.m/ha), the grassland plot yielded more runoff, which led to a higher total annual runoff as shown in Figure 71, and a higher median (Table 63). Thus grassland is more likely to contribute to flood events than rainfed agricultural land, especially during low and medium rainfall events. However, there were a number of situations in which the runoff from the rainfed agricultural land was higher than from the grassland. During the pre-monsoon, the rainfed agricultural land is fallow and infiltration capacity is lower than in areas where vegetation cover exists at this time of the year. Excess water is therefore more likely to run off, as shown during the first two major events in the year. The reason for the reversal on June 3rd has yet to be identified. During the monsoon, the occasions of higher runoff from the rainfed agricultural land coincided with the highest flows at the main station. But there were exceptions. The conditions which lead to these situations during the monsoon need to be investigated further.

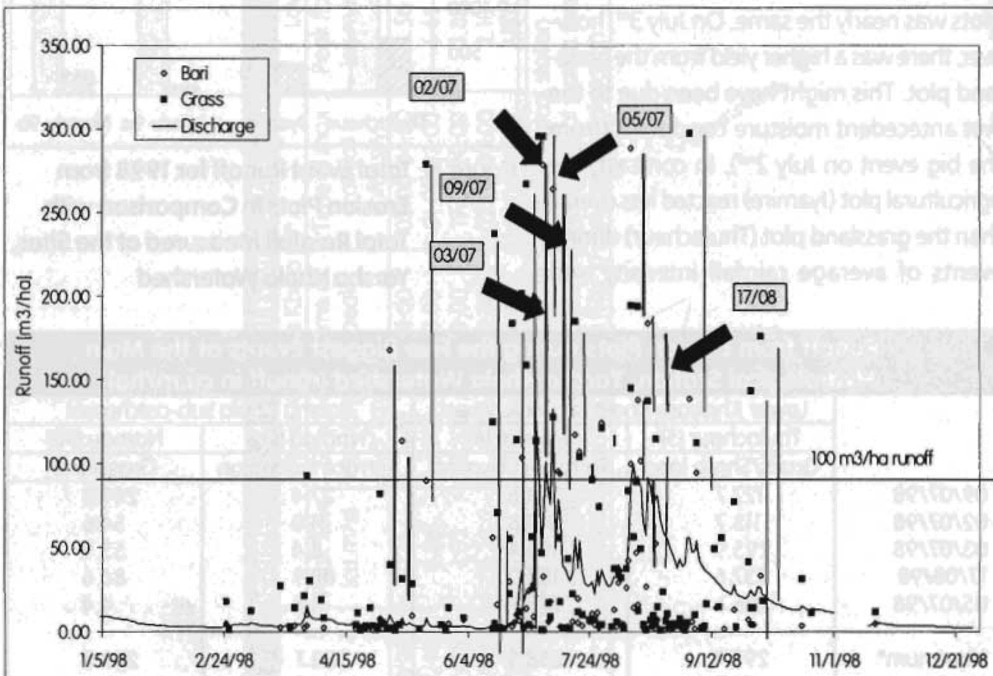

Figure 72: **Runoff from the Erosion Plots at Thulachaur (grass) and Jyamire (agricultural) (event based)**

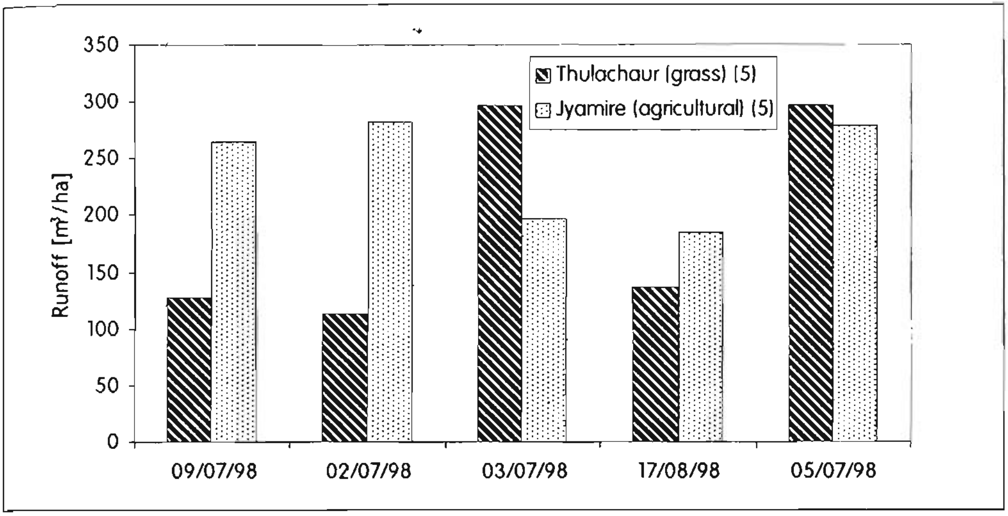

Figure 73: **Runoff from Selected Erosion Plots during the Biggest Events at the Main Hydrological Station**

Discussion

This study showed that there is a difference in the contribution from the different sub-catchments to the total discharge from the watershed. Although there is a difference in rainfall input between the different sub-catchments, this alone does not account for the different contribution.

During the monsoon, the Upper Khahare Khola (measured at Thulachaur), the sub-catchment with the highest portion of grass and shrub land, showed the biggest contribution to total discharge. Similarly, the annual runoff data from the erosion plots showed that grass/shrub land produced more runoff than cultivated terraces. It seems likely that as a result of the lack of cultivation and the relatively compact nature of the soil (a result of intensive grazing and animal trampling), the water retention capacity is lower during the monsoon in the grass/shrub land than in the rainfed agricultural land—which leads to a bigger contribution to discharge by the grass/shrub land dominated sub-catchments.

During high intensity storm events with high rainfall amount, both grassland and sloping agricultural terraces are likely to contribute to discharge as is shown in the erosion plot data. During the biggest events measured in terms of rainfall intensity and amount, rainfed agricultural land reacts intensively, and more than the grass/shrub land. This fact is likely to be important for investigations of high flood generation, and the conditions and reasons for this major response need to be studied closely. During these intense events on the sub-catchment scale, the yield of Bagar, with a high portion of sloping terraces and grass/shrub land, was even higher than that of Thulachaur.

Land cover (grass/shrub land or sloping terraces) clearly has an influence on the occurrence of high flow events, with a larger contribution from sloping terraces especially in the pre-monsoon season and during big events. Overall, however, grass/shrub land yields more than other types of land cover.

Conclusion

The most important events for flooding and stream bank erosion are the major events. The results show that during these events runoff is derived from all types of land cover and land use. Thus the influence of human activity on the generation of these major events in rural catchments is believed to be limited. The same conclusion has been reached in the Swiss Alps. On the other hand, medium-sized events might be influenced by land use changes and differences in land management practices. Carver (1995) reported that indigenous techniques are effective at low and intermediate flows, but less effective at high flows, regardless of land cover and season. A change in the area of agricultural land, as might happen with increasing population pressure and increasing demand from the markets in Kathmandu, might therefore have a major impact on the generation of small to medium flood events, but only a limited effect on big flood events.

However, conclusive remarks cannot be made at this stage as the results are based on the data from only one year, and the influence of forested catchments has yet to be investigated. Future studies will be focused on further understanding of the processes in areas with different land cover during major events, and a comparison of the responses to rainfall events from different types of land cover, land use, and land management practices.

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Rainfall Variation and Soil Erosion in the Bheta Gad Watershed of Uttar Pradesh in the Central Himalayas

Kesava R. Bontalakoti[1], Basant K. Joshi[1], Anil K. Mishra[1], Bhagavati P. Kothyari[1] and Ravindra K. Pande[2]

[1]G.B.Pant Institute of Himalayan Environment & Development, Kosi-Katarmal. Almora-263643

[2]D.S.B. Campus, Kumaun University, Nainital-263001

Abstract

The rainfall variation and soil erosion were measured at different locations and under different land uses in a central Himalayan watershed, the Bheta Gad. The watershed covers an area of 23 sq.km. Five standard rain gauges were placed at different elevations and aspects to represent approximately equal areas of the watershed. The total annual mean precipitation for the water year 1998 (1st October 1997 to 30th September 1998) was 168 cm. The soil erosion and nutrient losses were measured at four erosion plots (20x5m), each under a different land use and within the areas covered by the gauged stations. Four factors affecting the rainfall distribution in the watershed were estimated: slope, aspect, elevation, and the shadow zone effect. The rainfall intensity, aspect, and land use type all influenced the runoff and soil loss. During the study period, the watershed recorded a total effective precipitation (the precipitation causing runoff) of 139 cm in 58.5 effective rainy days, with an estimated average soil loss of 3.8 t/ha and surface runoff of 1582 cu.m/ha. The land use studies showed that the rate of infiltration decreases with an increase in soil compactness thus promoting runoff, and the rate of soil loss is directly correlated with increasing biotic interference, surface denudation, and degradation of land.

Introduction

The orographic complexities of the Himalayan region mean that climates are not uniform, and an extensive rainfall measurement network is required to accurately characterise precipitation patterns. Significant regional differences and wide variations in rainfall distribution have been recorded by Domraes and Manfred (1977). However, the spatial distribution of rainfall over a complex terrain has received little attention to date (Collinge *et al.* 1968). The effect of topography, at least in a broad sense, is to enhance the rainfall on slopes facing the winds and to produce a rain shadow zone on the leeward side. The enhancement of precipitation occurs as a result of lifting of air following the disturbances caused by the orography; this leads to cooling, condensation, and precipitation of the moisture. Several other factors like horizontal convergence, convective instability, and microphysical processes also play an important role in the precipitation mechanism in mountain regions, and processes are highly complex (Sarkar *et al.* 1978). The role of soil as the reservoir of the nutrient and moisture reserves which influence bio-mass production has long been recognised (Klemmedson 1970). However, the natural biodiversity that can be supported by a given soil type is largely determined by the amount and distribution of precipitation (Rauzi and Hanson 1966). Surface runoff, water intake, and sediment transportation rates vary with land use management, soil type, and slope aspect and orientation, as well as with the biophysical processes within the land use system. Soil erosion is a selective process that diminishes soil fertility, plant growth, and crop production. The four erosion plots in this study were established on land used for different purposes with different physical attributes to allow the impact of various factors to be assessed.

The Study Area

The Bheta Gad watershed, a sub watershed of the Garur Ganga river, which is a tributary of the Gomati river in the Kumaun hills of the central Himalayas, was selected for this study (Figure 74). The watershed has an area of 23 sq. km. It is situated 60 km north of Almora in Uttar Pradesh (UP) between the coordinates 29°50'23" and 29°55'56" N and 79°02'59" and 79°30'04" E. The watershed lies between 1090 and 2520 masl and is characterised by a temperate climate with three pronounced seasons—summer, winter, and rainy. The Kumaun Himalaya can be divided into five WNW-ESE trend linear lithotectonic units, the Tethyan, Central, Garhwal, Kumaun, and Siwalik, each separated by major faults. The study area itself shows the development of stratigraphic sequences similar to those of Himachal and Garhwal, comprising a more or less continuous sequence of Late Precambrian to Early Cambrian formations. The Rameswar, Berinag quartzite, and Nagthat formations with their meta volcanic constituents are the extensive basal sedimentary formations. These are succeeded by the Pithoragarh (Tejam) formation, with Lower and Middle Riphean stromatolite-bearing Gangolihat Dolomite, followed by the Rautgora formation, which can be correlated with the Damtha group, and Simla slate. The carbonate horizons show prolific development of branching columnar stromatolites. The average aspect of the watershed is north-west, the shape elongated and the drainage pattern dendritic.

The watershed has a total population of 8,368 (1991 census). Agriculture is the main occupation. The major crops are rice, wheat, barley, millets, pulses, mustard, potatoes, and soya beans. Pine trees (*Pinus roxburghii*) are the dominant forest species.

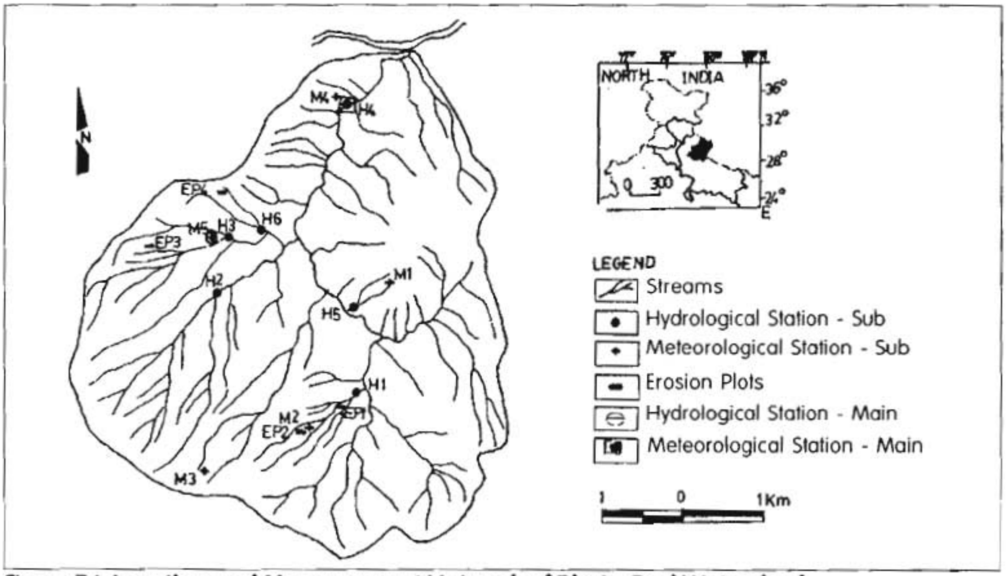

Figure 74: **Location and Measurement Network of Bheta Gad Watershed**

The Rainfall Pattern in the UP Central Himalayas

The spatial temporal distribution of rainfall in the UP Himalayas is highly variable, but most of the rainfall in the region is caused by the south-west monsoon and in general more than 80 per cent of the annual precipitation occurs during the three-month monsoon period from mid June to mid September. In the western hills of UP, 1576 mm of the 1969 mm average annual precipitation falls during this period (Statistical Diary 1973). Even within this period, the major part of the rainfall occurs in a few storms. When the monsoon winds arrive, they assume a south-westerly direction. In regional and general terms, the volume of rainfall gradually decreases from the south-west to the north-east.

Methodology

Rainfall Measurements

In order to obtain satisfactory data on rainfall distribution within the study watershed, a network of five standard non-recording rain gauges (Symon's rain gauge) was installed at different elevations. These instruments consist of a funnel with a beveled gunmetal rim 127 mm in diameter, and a receiver with a narrow neck and a splayed base which is fixed at 1m above ground level. The rainfall data was collected at 8:30 am (IST) every day. In addition, tipping bucket rain gauges were installed, four of them at the erosion plots, and one at the main station in Lawbanj. These instruments collect the rainfall and strain it through a metal gauge before passing it on to the tipping bucket mechanism. Tips of the bucket occur with each 0.2 mm of precipitation collected and each tip is recorded on a logger. The stored information was downloaded every few months to a portable computer.

For the analysis, the study area was divided into various zones based on the position of the meteorological observation stations (thus reflecting the influence of different factors) using Thiessen polygons (Figure 75).

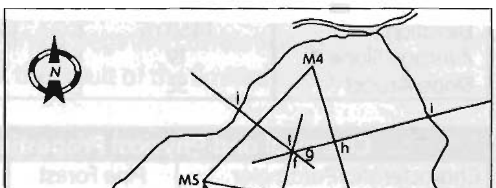

Figure 75: **Thiessen Mean Method to Calculate the Mean Annual Precipitation and Estimation of Influencing Area of Meteorological Observation Station**

Daily 24-hour rainfall was recorded from the gauge network. Monthly rainfall data from 1st October 1997 to 30th September 1998 were used in the analysis.

The Erosion Plot Monitoring System

Four erosion plots were set-up, one each in a pine forest, tea-plantation (recently planted), on rainfed agricultural land, and degraded pasture land. The location and physico-chemical characteristics of the erosion plots are shown in Tables 64 and 65. The approximate slope of the erosion plots varied from 2 to 28 per cent. The pine forest, tea estate, and grazing plots were established on moderate to steep slopes, but the rainfed agricultural land was on a very gentle slope.

The methods of analysis followed those given in Jackson (1962) and Allen (1989). Each erosion plot was enclosed by a 50 cm high metal sheet coated with iron oxide, 20 cm of it inserted vertically into the ground and 30 cm above the surface. The surface runoff from each erosion plot was collected in two tanks via a gutter and a multi slot devisor. The gutter drains the runoff into a 200 litre tank, which overflows into a second tank via a seven slot multislot devisor which allowed 1/7th of the overflow into the second tank through the middle slot. The actual amount of overflow is determined from the amount in the second tank using a calibration curve. The total sediment (soil loss from the plot) was estimated using a composite sample collected from both tanks, after preliminary tests showed no significant difference between the mean of separate samples collected from each drum and a thrice replicated composite sample. The concentration of the suspended material was determined by a filtration method (Heron 1990; Hudson 1993). The sediment retained after filtration (Whatmann No.1 filter, pore size 1.2 mm) was dried at 105°C for 24 hours, weighed, and compared with an equal volume of pure water treated in the same way as a control. The weight of sediment was converted into sediment yield in t/ha (Heron1990; Hudson 1993). Nutrient loss was analysed following the methods of Jackson (1962).

Table 64: **Location and Characteristics of the Erosion Plots**

Characteristic/ Parameter	Pine Forest	Tea Plantation	Rainfed Agriculture	Degraded Pasture
Location	Majhar chaura	Gewar	Kaulaug	Khaderiya
Elevation	1460 m	1620 m	1390 m	1350 m
Average Slope %	19	20	2	28
Slope Aspect	SE	E	E	S

Table 65: **Chemical and Physical Properties of the Soil at the Erosion Plots**

Characteristic/Parameter	Pine Forest	Tea Plantation	Rainfed Agriculture	Degraded Pasture
CEC (meq/100g)	8.68	14.56	11.79	12.16
pH	6.39	6.16	6.24	6.84
OM (%)	2.29	2.55	3.04	1.64
Available P (kg/ha), as P_2O_5	38.3	38.3	22.9	11.8
Available K (kg/ha), as K_2O	229	286	315	137
Infiltration Rate (cm/hr)	5.8	8.7	4.2	10.6
Bulk Density (g/cc)	1.43	1.15	1.05	1.31
Colour	Light grey	Greyish Brown	Light Grey	Reddish Brown
Texture	SL	SL	SL	LS
Sand	63	66	61	73
Silt	22	25	23	16
Clay	15	09	16	11
WHC (%)	30.8	31.9	34.1	29.6

Note: CEC = Cation Exchange Capacity; OM= Organic Matter; SL= Sandy Loam; LS = Loamy Sand; WHC = Water Holding Capacity.

Results and Discussion

The Rainfall Variation in the Watershed

Table 66 shows the seasonal rainfall variation against elevation and aspect at the different meteorological observation sites in the watershed.

Overall the watershed received an annual total rainfall of 168 cm during the water year 1998, with maximum intensities for 30 minutes and 24 hours of 5.2 and 4.6 mm/hr respectively. The tea estate station (M2 at 1620m) received the highest monsoon, summer, and annual total rainfall (1117, 487, and 1748 mm respectively). The lowest elevation station Lohari (M4 at 1077mt) received the lowest annual total rainfall and monsoon rainfall (1576 and 963 mm respectively).

Table 66: **Seasonal Rainfall Variation Against Elevation and Aspect in the Bheta Gad Watershed**

Station No.	Location of Meteorological Station	Winter Rainfall (mm)	Summer Rainfall (mm)	Monsoon Rainfall (mm)	Annual Total Rain-fall (mm)	Slope Aspect	Elevation (masl)
M4	Lohari	197.0	416.8	962.5	1576.3	NE	1077
M5	Lawbanj	185.2	417.0	1101.9	1704.3	NE	1349
M1	Patli	197.0	337.7	1093.8	1628.5	SW	1382
M2	Tea-Estate	145.0	486.7	1116.6	1748.3	NE	1620
M3	Kausani	183.9	467.7	1066.2	1717.8	NE	1840

Figure 76 shows plots of the rainfall against altitude in the three seasons winter, summer and monsoon. There was a positive correlation between the altitude and the amount of rainfall in the summer and monsoon seasons, and a negative correlation in winter. The R^2 values indicated that the regressions were poor, the result of the limited size of the data set.

Analysis of the Soil Erosion under Different Types of Land Use

The effective precipitation, surface runoff, and soil losses for the different erosion plots in the three seasons are shown in Table 67, and the annual values illustrated in Figure 77. The effective precipitation varied from 75 to 1020 mm. In the pine forest and tea-plantation plots, runoff was generated by storms with an intensity of 1.38 mm/hr or more; in the rainfed agricultural land and degraded pasture land plots intensities of 3.09mm/hr or more were required. The highest effective precipitation, surface runoff, and soil loss were observed in the monsoon season (Table 67). The amount of runoff was influenced by the slope, land use, and soil type, as well as by the precipitation. The surface runoff during the summer was considerably less than in the monsoon season at all sites. However, at the rainfed agricultural site the soil loss during the summer was disproportionately high, as were the runoff and soil loss during the winter, probably as a result of the direct impact of raindrops on a bare soil surface.

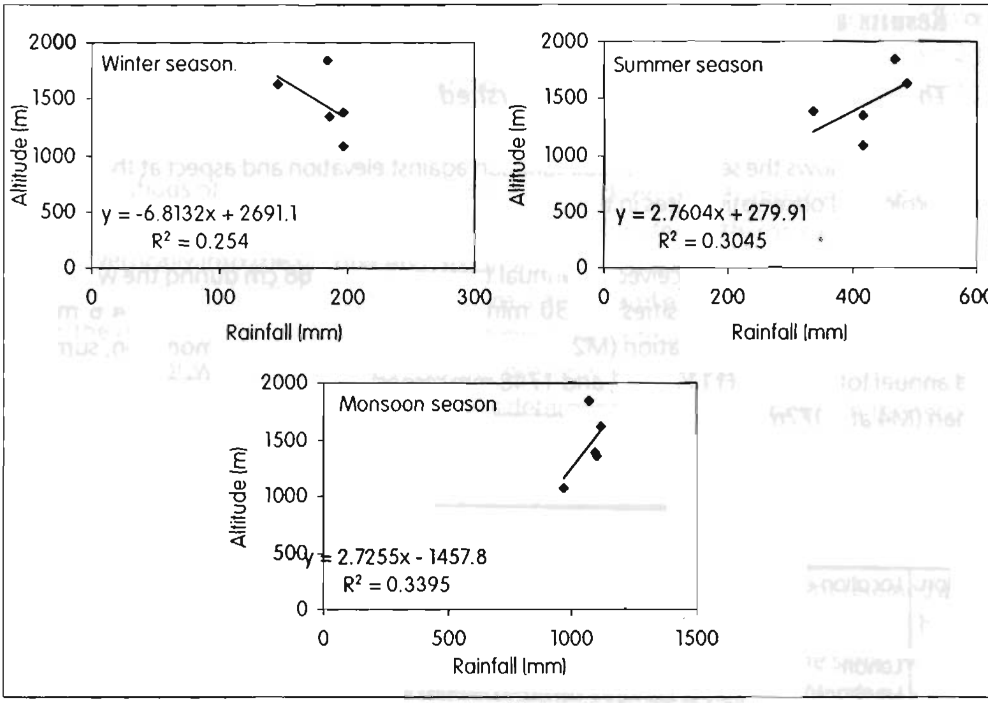

Figure 76: **Total Rainfall versus Altitude in the Winter, Summer and Monsoon Seasons**

Over the whole of the water year, the surface runoff was highest from the pine forest and least from the rainfed agriculture plot. The pine forest site was situated on a steep slope and had a compact soil surface, which promotes surface runoff. The findings are comparable with the observations of Mwendra and Saleem (1997).

During the winter and summer seasons, the highest soil losses were recorded at the tea plantation (1.8 t/ha and 2.2 t/ha respectively), and the lowest at the rainfed agriculture plot (0.3 t/ha and 0.2 t/ha). In the monsoon season, the highest soil loss was observed at the pine forest plot (4.0 t/ha) and the lowest at the rainfed agriculture plot (0.2 t/ha). The high soil loss at the tea plantation was probably the result of the bare soil in the inter-row strips—mulching would assist in controlling erosion from this area. The high soil loss during the monsoon season at the pine forest plot was the result of intensive grazing, litter collection practices, and the steep slope.

The nutrient losses for the different erosion plots in the three seasons are shown in Table 67. The relationship between the annual effective precipitation and loss of organic matter and total phosphorus for the four different land use types is illustrated in Figure 77(b). The nutrient loss estimates for the areas under different land use show a significant seasonal variation in soil organic matter loss (Table 67). There was no direct relationship between organic matter loss and soil loss in the tea plantation and pasture land. In the first case this resulted from the amended soil and weeding practices in the recently planted tea-plantation: the newly exposed nutrients were washed away in the first few storms. Samples collected

Table 67: **Seasonal Variation in Precipitation , Runoff, and Soil Losses for the Different Erosion Plots**

Erosion plot site	Effective precipitation (mm)			Surface Runoff (mm)			Soil Loss (t/ha)		
	Winter	Summer	Mon-soon	Winter	Summer	Mon-soon	Winter	Summer	Mon-soon
Pine Forest	144.1	381.9	938.1	26.4	105.9	179.9	1.2	1.4	4.0
Tea-plantation	144.1	381.1	924.6	23.0	60.8	77.5	1.8	2.2	2.3
Rainfed Agri. Land	74.5	302.8	776.2	9.3	4.2	16.8	0.3	0.2	0.2
Degra. Pas. Land	113.7	356.6	1019.6	13.0	34.2	81.8	0.4	0.5	0.9

Table 67: **Seasonal Variation in Precipitation , Runoff, and Soil Losses for the Different Erosion Plots (cont'd)**

Erosion plot site	Org. Matter Loss (kg/ha)			Total Phosphorus (kg/ha)		
	Winter	Summer	Mon-soon	Winter	Summer	Mon-soon
Pine Forest	92.1	47.5	171.8	2.5	2.3	5.8
Tea-plantation	193.2	100.8	112.1	5.0	3.6	2.0
Rainfed Agri. Land	21.8	15.7	10.1	0.7	0.5	0.5
Degra. Pas. Land	55.0	14.5	52.7	0.6	0.6	1.3

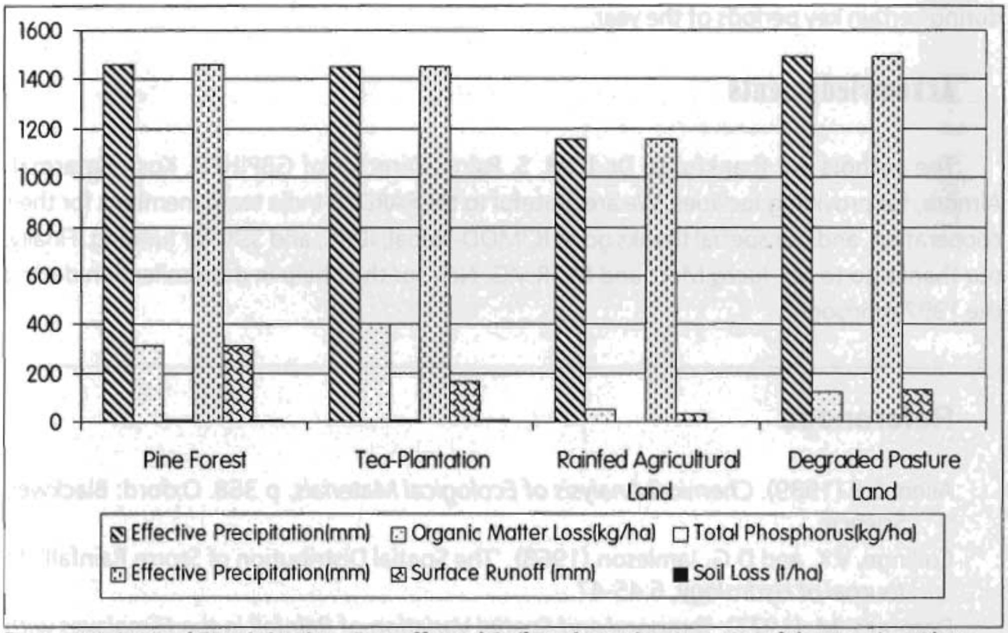

Figure 77: **Annual Precipitation, Runoff, and Soil and Nutrient Losses of the Erosion Plots**

later, in the monsoon, showed a lower organic matter loss but a higher soil loss. In the second case the degraded pasture land had little surface soil cover; the soil loss observed in the samples was mostly weathered rock mass. The area was kept open for grazing from winter to early monsoon and was closed by social fencing for a couple of months in the monsoon; thus the biomass residues decreased from winter to the summer when less organic matter loss was observed in the samples. The loss of phosphorus from the four different plots ranged from 0.5 to 5.8 kg/ha in the different seasons (Table 67).

Conclusions

Data from several successive water years is required for a significant comparative study. In this paper, an attempt has been made to present a few of the findings for the water year 1998 on the basis of meteorological and soil erosion data. Based on these very preliminary findings, some suggestions were made to farmers about suitable sowing times, crop irrigation requirements, the need for water storage for the dry periods, and the risk of potential losses of organic matter and other soil nutrients.

Tea gardens are being developed in the Bheta Gad watershed at an increasing rate, and both tea project staff and farmers need to be aware of the soil losses that can occur in new plantations. The precautionary measures needed to prevent runoff and subsequent soil loss are proper drainage, mulching, maintenance of gentle slopes, and possibly leguminous cover crops in the inter-row areas.

The high losses recorded in the pine forest plot suggest that serious thought needs to be given to some form of rotational system whereby litter collection and cattle grazing in areas of the forest vulnerable to runoff and soil loss (e.g., steep south westerly slopes) are restricted during certain key periods of the year.

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Erosion Dynamics in the Jhikhu and Yarsha Khola Watersheds in Nepal

Gopal Nakarmi [1], Hans Schreier [2], Juerg Merz [3], Prakash Mathema [4]
[1] PARDYP, International Centre for Integrated Mountain Development (ICIMOD)
[2] Institute for Resource and Environment, University of British Columbia, Vancouver, Canada
[3] PARDYP/Department of Geography, University of Bern, Switzerland
[4] Department of Soil Conservation and Water Management (DSCWM), Kathmandu, Nepal

have a direct influence on the physical and chemical properties of soil and on soil nutrient losses. Accelerated erosion threatens the sustainability of mountain farming systems, and seriously affects the hydrological regime and sediment transport processes downstream. To quantify the rate of erosion, test plots were established in the Jhikhu Khola watershed in 1992; the network was expanded to the Yarsha Khola watershed in 1997. Plots were installed on rainfed agricultural land, grazing land, and degraded sites. Rainfall amount, intensity, and duration are the critical factors, apart from management and site conditions, that influence rates of erosion. Seasonal effects also play a key role. Past data show that the two most damaging storm events can produce 50 to 90 per cent of the total soil loss in a year. These storms typically occur during the pre-monsoon season. In this paper, the overall effects of rainfall on runoff and soil loss are investigated.

In cultivated fields, the overall effect of rainfall on surface runoff was minimal when rainfall events were less than 20mm. In contrast, there was a close relationship between rainfall and runoff in grassland and degraded sites; but runoff from grassland contained very little sediment, the highest erosion rates were from degraded sites. At very high rainfall volumes, soil loss rates were of a similar order of magnitude for both degraded and cultivated sites. More than 90 per cent of the total annual erosion occurred in less than 15 annual events, suggesting that the timing of these needs to be examined more closely before any positive preventative actions to mitigate erosion can be suggested.

Introduction

Soil erosion processes lead to soil removal, losses in organic matter that affect the physical and chemical properties of the soil, and soil nutrient losses. Accelerated erosion therefore threatens the sustainability of mountain farming systems and seriously affects the hydrological regime and sediment transport processes downstream (e.g., by clogging up the irrigation network). Carver and Schreier (1995) established a close link between nutrient loss and soil movement from rainfed sites in the Jhikhu Khola Watershed (JKW). The rate of land denudation depends upon land management, particularly the maintenance of ground cover condition (Carver and Nakarmi 1995; Hashim *et al.* 1995). In order to quantify the rate of erosion, test plots were established in the Jhikhu Khola watershed (JKW) in 1992. The network was expanded to the Yarsha Khola watershed (YKW) in 1997. The plots are rectangular and each covers 100 sq.m. (20 x 5 m). A total of eleven plots were established in the two watersheds, seven on rainfed agricultural land, two on grazing land, and two on degraded sites. In addition to management and site conditions, the critical factors that influence rates of erosion are amount, intensity, and duration of rainfall. Carver (1997) suggested that in the JKW the threshold value above which rainfall intensity causes surface erosion is 30 mm/hr. Seasonal effects play a key role, and past data indicate that the two most damaging storm events in a year usually produce between 50 and 90 per cent of the total soil loss in that year, these storms typically occurring during the pre-monsoon season (Carver and Nakarmi 1995; Nakarmi 1998). This paper describes the results of an investigation into the overall effects of rainfall on runoff and soil loss.

Site Location and Study Approach

The JKW lies about 45 km east of Kathmandu between 27°33′ and 27°42′ N, and 85°31′ and 85°41′ E, with an altitude range from 860 to 2200 masl. The YKW lies about 180 km north-east of Kathmandu between 27°34′ and 27°40 N and 86°05′ and 86°11′ E, with an altitude range from 1000 to 3200 masl. The YKW is accessible from the Lamusangu-Jiri road. There are striking differences between the two watersheds. The JKW is closer to markets (Kathmandu) and is subject to much higher land use pressures, with the result that triple annual crop rotations and cash crop production are common. In contrast, the YKW is far from main markets and is dominated by subsistence farming.

Five erosion plots were established on sloping agricultural land in the JKW in 1992, and two new plots on degraded sites were added in 1997. The plots are monitored on a daily basis, and runoff and sediment content are determined on a storm by storm basis; all stations are equipped with an automated tipping bucket rain gauge for continuous monitoring of rainfall events. Table 68 shows the physical characteristics of the plots. Four erosion plots were monitored in the YKW in 1997 and 1998, two on grazing land and two on rainfed agricultural land. All plots on rainfed agricultural land cover two terraces and one terrace riser, but otherwise the site conditions at the rainfed plots are highly variable. This complicates such studies, so for the purpose of this paper data are only presented for two of the four agricultural plots in the JKW.

Table 68: **Physical Parameters of Erosion Plots**

Plot No.	Location	Land use	Slope (°)	Elevation (m)	Aspect	Remarks
Jhikhu Khola Watershed						
JE 4	Luitelgaun	Degraded	12	1040	North	Red soil
JE 14	Kubinde	Degraded	15	1010	South	Red soil
JE 6b	Bela	Rainfed cultivation	18	1345	North	Red soil
JE 16	Bhetwalthok	Rainfed cultivation	15	1365	South	Coarse red soil
Yarsha Khola Watershed						
YE 5	Thulachaur	Grassland	19	2300	South	Dark brown soil
YE 9b	Namdu	Grassland	17	1410	South	Red soil
YE 6	Jyamire	Rainfed cultivation	17	1980	South	Brownish red soil
YE 9a	Namdu	Rainfed cultivation	18	1420	South	Red soil

The rainfed test plots in both watersheds are managed by farmers who are also responsible for keeping the records for erosion and runoff. Maize is the principal crop in both areas with millet as a secondary crop in the YKW and wheat as the dominant second crop in the JKW.

Results

Rainfall Characteristics

The amount, duration, and intensity of rainfall are the key external factors affecting erosion. The higher the energy of the falling rain, the greater is the power to detach soil particles—which are subsequently moved by the runoff water. In this paper, the effect of rainfall variability at the erosion plots on runoff and erosion is examined over the 1997 and 1998 period.

Four rainfall stations in the JKW and three stations in the YKW were used to analyse the annual and event-based rainfall. Figure 78 shows the monthly rainfall distribution in the JKW for 1998. The highest rainfall occurred during July followed by August. The elevation difference between the four stations is relatively small (305m on the north facing slope and 355m on the south facing side) and this is the main reason for the relatively small monthly difference between the stations. Only in May, during the pre-monsoon period, was there any marked difference. At this time the low elevation south-facing station received around fifty per cent more rainfall than the other stations.

Figure 79 shows the monthly rainfall distribution for the three stations in the YKW in 1998. There is a much greater elevation difference between these stations, and the influence of this elevation gradient is reflected in the differences in the monthly rainfall totals. The lowest station Namdu (1410m) received the lowest monthly rainfall throughout the monsoon, and the highest station Thulachaur (2300m) the highest rainfall. The differences were most pronounced in June and July.

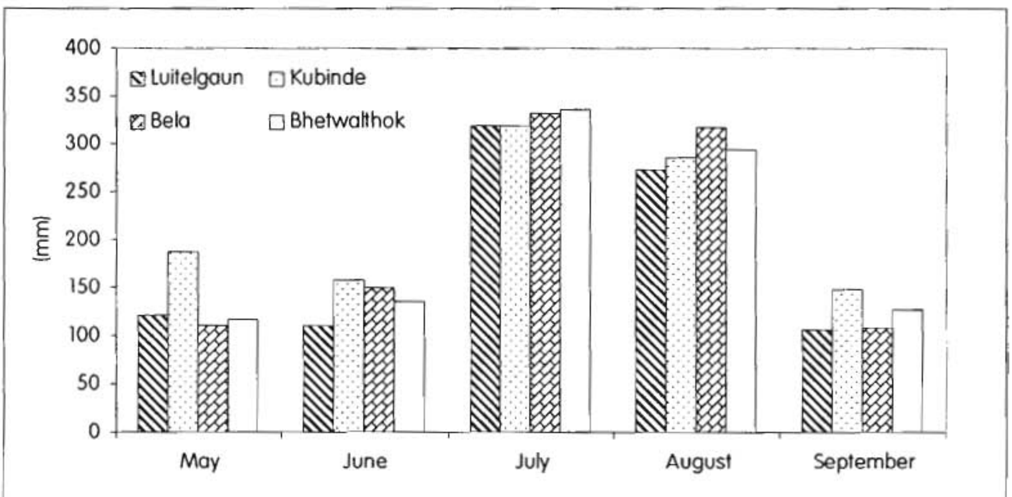

Figure 78: **Monthly Rainfall Distribution in the JKW during the 1998 Rainy Season**

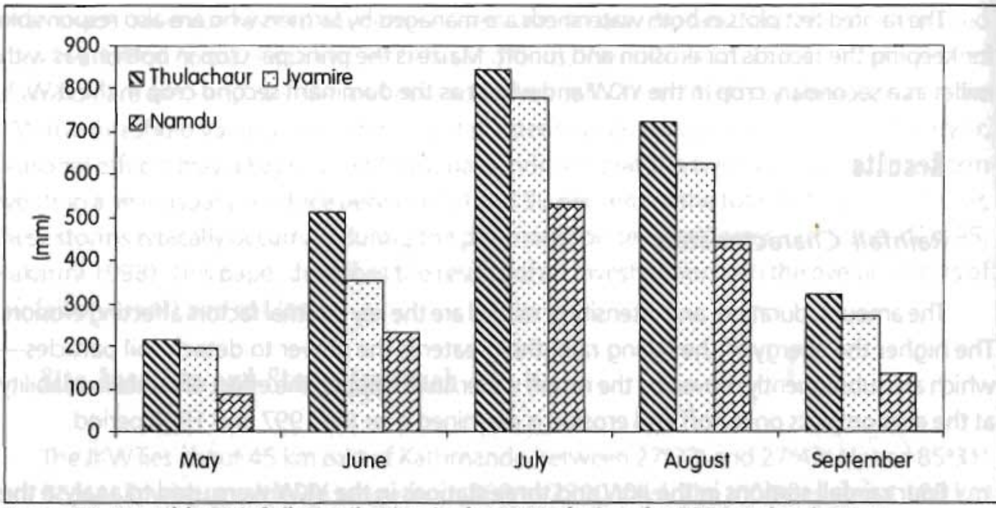

Figure 79: **Monthly Rainfall Distribution in the YKW during the 1998 Rainy Season**

Figure 80 shows the total monsoon precipitation in both watersheds in 1997 and 1998 rainy seasons. The values for 1997 and 1998 were very similar in the lower elevation Jhiku Khola watershed but not in the higher elevation Yarsha Khola watershed. This suggests that annual variations may be more marked at higher elevations, although longer-term records will need to be analysed to confirm this.

Runoff versus Rainfall

Runoff from the 100 sq.m. erosion plots was collected in drums and measured. Runoff values were determined for the two degraded and two cultivated sites in the JKW, and the two grassland and two cultivated sites in the YKW. Figures 81 to 84 show the rainfall/runoff

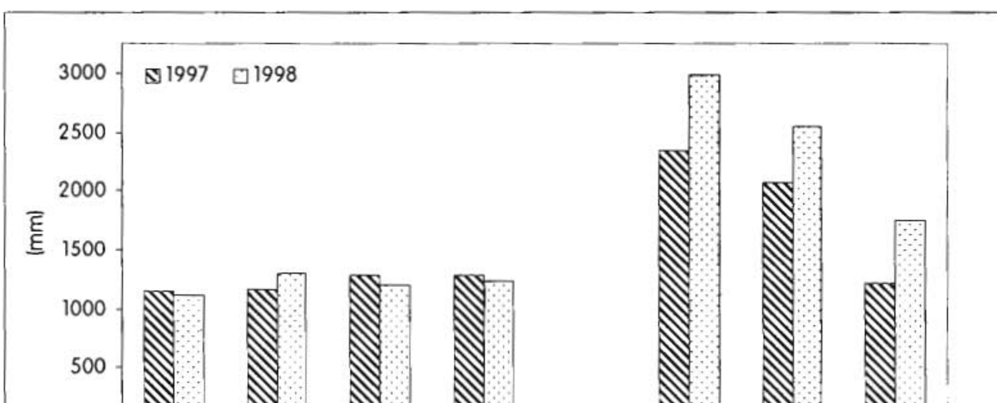

Figure 80: **Comparison of Rainy Season Rainfall Distribution in 1997 and 1998 in the JKW and the YKW**

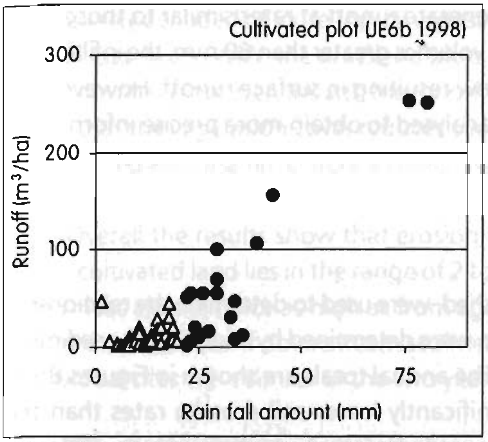

Figure 81: **Runoff by Event from Cultivated Plot, JKW**

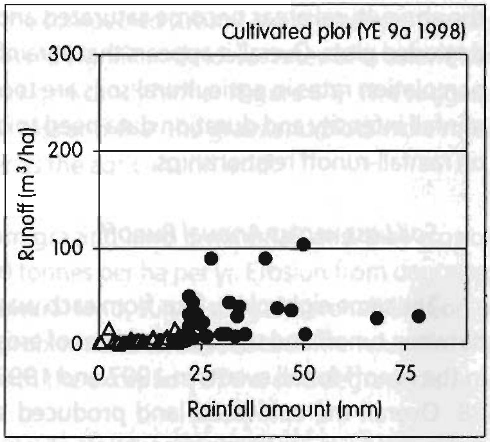

Figure 82: **Runoff by Event from Cultivated Plot, YKW**

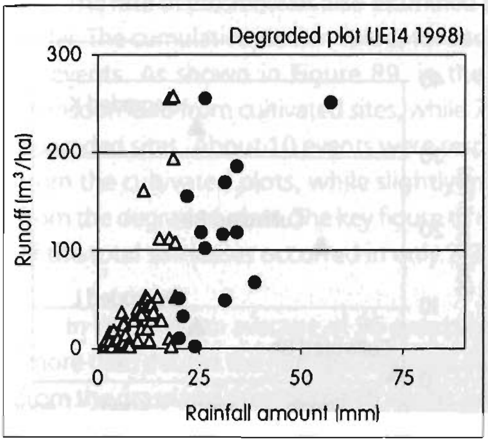

Figure 83: **Runoff by Event from Degraded Plot, JKW**

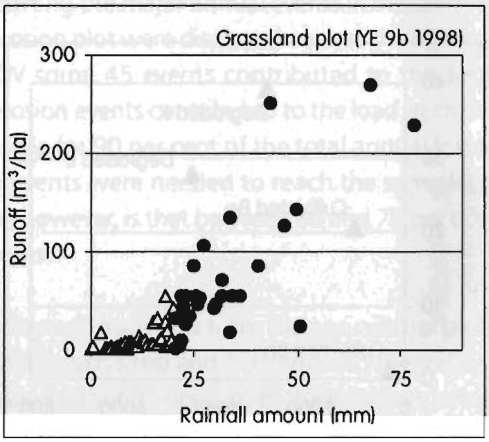

Figure 84: **Runoff by Event from Grassland Site, YKW**

relationships for one site of each type as an example for all events recorded in 1997 and 1998. Events with less than 20mm of rainfall are indicated by a pale triangle, those with more than 20mm of total rainfall by a black dot.

During low rainfall events (<20 mm), there was little or no runoff from the cultivated sites, and only a very small amount from the grassland sites, but the runoff from degraded sites was substantial (Figure 81). The runoff for rainfall events of 20-40 mm reached 100 m^3/ha from both cultivated and grassland plots, with slightly higher values from grassland, but the values were significantly higher from the degraded sites reaching more than 200 m^3/ha. Only at very high rainfall events of around 80 mm did the runoff values from some cultivated sites reach similar values to those from the grazing and degraded sites.

Thus it appears that during storms with low amounts of rainfall, water in agricultural areas infiltrates the soil and is stored, resulting in minimal runoff, while in degraded land little water infiltrates the surface and the runoff is much higher. Only in very high rainfall events do the agricultural areas become saturated and generate runoff at rates similar to those from degraded plots. Overall it appears that at rainfall volumes greater than 60 mm, the infiltration/percolation rates in agricultural soils are too slow resulting in surface runoff. However, the rainfall intensity and duration data need to be analysed to obtain more precise information on rainfall-runoff relationships.

Soil Loss versus Annual Runoff

The same eight plots, four from each watershed, were used to determine the relationship between runoff and soil loss. The rates of erosion were determined by analysing the sediment in the runoff for all events in 1997 and 1998. The annual totals are shown in Figures 85 to 88. Overall the cultivated land produced significantly lower soil erosion rates than the degraded lands, with the exception of one degraded plot which showed a much lower erosion rate, but still with high run off, in the second year. This site had become almost

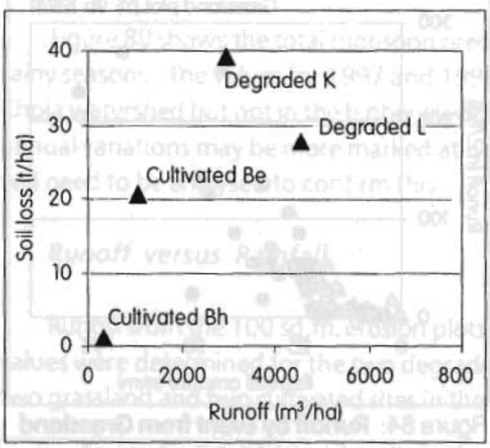

Figure 85: **Annual Soil Loss versus Runoff, JKW, 1997**

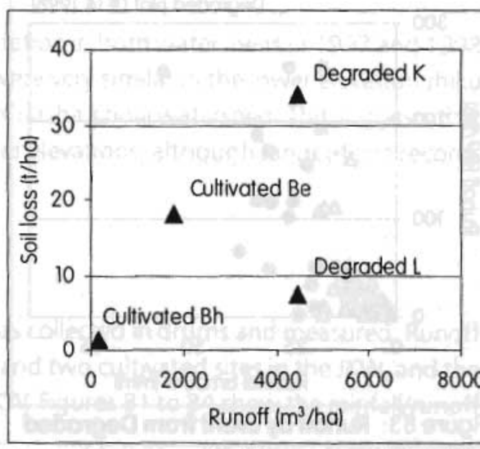

Figure 86: **Annual Soil Loss versus Runoff, JKW, 1998**

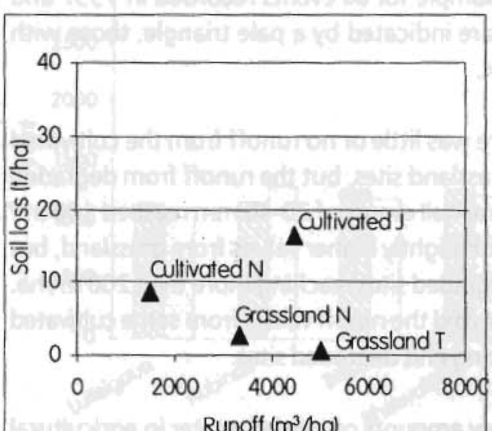

Figure 87: **Annual Soil Loss versus Runoff, YKW, 1997**

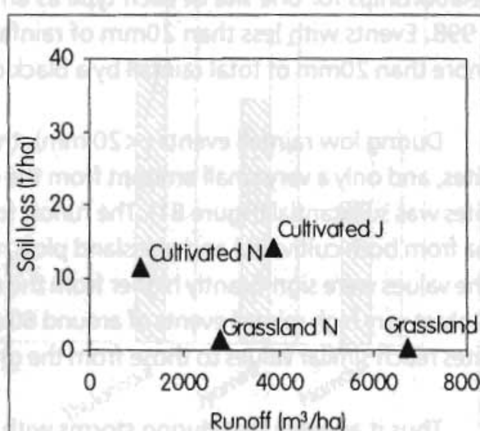

Figure 88: **Annual Soil loss Versus Runoff, YKW, 1998**

completely denuded of loose topsoil exposing the compacted subsoil, which reduces the rate of soil loss. In the YKW, the grassland plots showed significantly lower rates of erosion than the cultivated plots even though the runoff was significantly higher (Figure 84). This suggests both that the vegetation cover reduces the soil loss and that the grassland plots were more compacted and unable to store as much water as the agricultural land.

Overall the results show that erosion from grazing land is minimal, and that erosion from cultivated land lies in the range of 2 to 20 tonnes per ha per yr. Erosion from degraded lands was almost twice as high as from agricultural land, suggesting that rehabilitation of these lands is critical if downstream sediment problems are to be reduced. The values for the individual sites were similar in the two years with the exception of the one degraded site.

The Role of Critical Events

The rate of erosion was also examined by sorting the major annual events in descending order. The cumulative erosion values for each erosion plot were displayed against the number of events. As shown in Figure 89, in the JKW some 45 events contributed to the total monsoon load from cultivated sites, while 70 erosion events contributed to the load from the degraded sites. About 10 events were responsible for 90 per cent of the total annual losses from the cultivated plots, while slightly more events were needed to reach the same level from the degraded plots. The key figure to note, however, is that between 60 and 70 per cent of the total soil losses occurred in only 2-3 events.

In the YKW, an average of 96 events contributed to soil loss from the agricultural plots (more than double the number recorded in JKW for such sites) and 110 events to the soil loss from the grassland sites. Some 15 events generated about 90 per cent of the total annual soil loss in all sites (Figure 90).

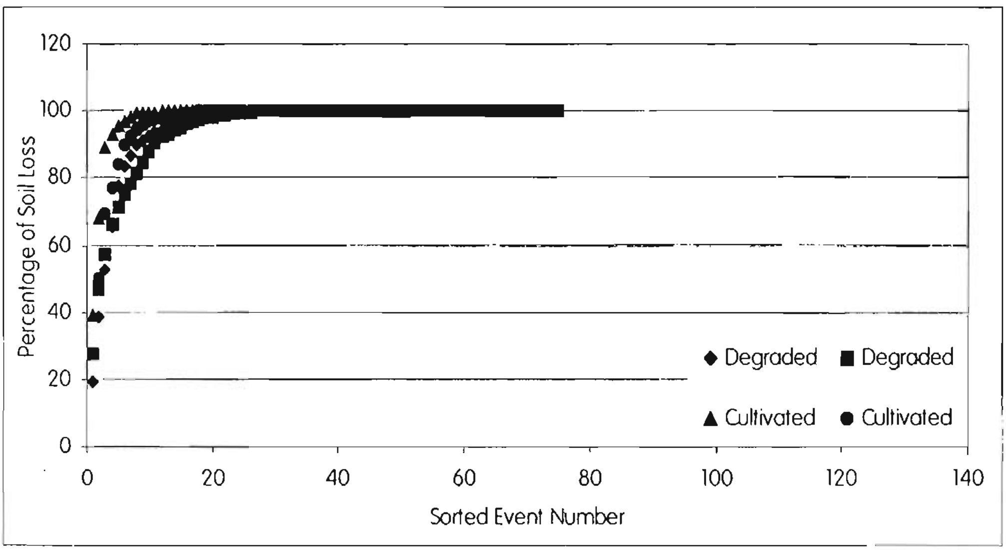

Figure 89: **Cumulative Soil Losses in the JKW by Event, 1998**

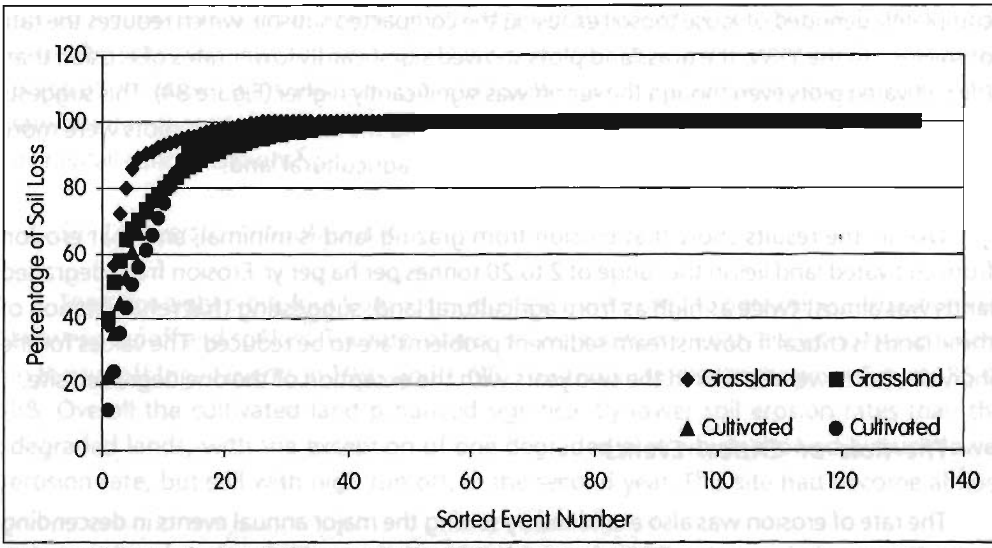

Figure 90: **Cumulative Soil Losses in the YKW by Event, 1998**

Predicting when the few major storms will occur that are responsible for 60-80 per cent of the soil losses remains the main challenge. Clearly, greater attention needs to be directed towards these events and their intensities and duration because they are the most destructive to the environment, and the most detrimental to the farmers in terms of topsoil and nutrient loss.

Conclusions

Almost twice as much rain fell in the higher elevation YKW during the wet months (July–September) as in the lower elevation JKW. July was the wettest month at all stations in both 1997 and 1998. There was hardly any variation in the annual totals in 1997 and 1998 between the lower elevation stations in the two watersheds, but significant differences were found at the higher elevations. The Yarsha Khola watershed showed a clear altitudinal gradient, with annual precipitation at the highest station almost twice that at the lower station. The altitudinal increase was approximately 10 mm increase in rainfall per 100 m increase in elevation.

The overall effect of rainfall on surface runoff was minimal in cultivated fields when rainfall events were less than 20mm, and on grazing land when rainfall was less than 18 mm. A close relationship between rainfall and runoff was observed in grassland and degraded sites when rainfall events exceeded 20mm; the main difference between the two was that runoff from grassland contained very little sediment, whereas erosion rates in the degraded sites were high. At very high rainfall volumes, the soil loss rates from degraded sites and cultivated sites were of a similar order of magnitude.

The degraded land in the JKW generated between 28 and 39 tonnes of sediment per ha per year with a total runoff of 3,000 to 5,000 m^3/ha; in contrast, grassland released less than

3 t/ha. Cultivated fields generated between 1 and 20 t/ha with a total runoff of 1,000 to 4,500 m^3/ha. These findings indicate the following.

- Water storage in the soil is less effective in grazing land than in agricultural land.
- Erosion problems are worse on cultivated sites than on grazing land.
- Degraded areas are the main source of sediment.
- Changes in land management and land cover would have little effect on soil loss rates during high volume rain storms unless there was some way of ensuring that cultivated land had a 'mat' of vegetation during the premonsoon and monsoon seasons.
- Soil compaction influences infiltration rates and soil water storage capacity, and these are key elements in the relationships between rainfall, runoff, soil loss, and land use.

Finally, more than 90 per cent of the total annual erosion occurred in less than 15 annual events, suggesting that the timing of these needs to be examined more closely before positive preventative actions to mitigate erosion can be suggested.

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An Assessment of the Water Need and Supply Situation in a Rural Watershed of the Middle Mountains in Nepal

Juerg Merz[1], Bhuban Shrestha[2], Bhawani S. Dongol[2], Madhav P. Dhakal[2], Rolf Weingartner[1]

[1] PARDYP/University of Bern

[2] PARDYP/International Centre for Integrated Mountain Development

Abstract

Water supply is critical in many areas of the middle mountains in Nepal. In order to assess the situation in a rural watershed, a survey was conducted of the present situation of water need and supply in the Yarsha Khola watershed. The survey was designed to investigate water demand, water problems, water supply, and other water related issues.

The major hardships in terms of drinking water were experienced in the high altitude areas along the watershed boundary and along the ridges in the watershed. Shortages of irrigation water were mainly encountered in winter when water was needed for cultivation of wheat and potato. Possible improvements within the framework of PARDYP are discussed, and further activities for Phase II of the project suggested.

Introduction

"Without water no life"–one of the perceptions of water often mentioned by the people interviewed in the Yarsha Khola watershed. Although the importance of water is well known, it is in short supply in many parts of the Hindu Kush-Himalayas (HKH), and both water quantity and water quality issues are of increasing concern. The population is growing and the pressure on the resource is increasing as a result of the growing need for water for both household and agricultural use. Rising temperatures and more extreme events resulting from climate change might further increase the pressure on water resources—or they might reduce the pressure as a result of increased precipitation (FAO 1995) providing sound management systems are employed. Intensive farming with increasing use of chemical fertilisers and pesticides is reducing the water quality of micro to meso-watersheds. The influence on big river systems in the region is not well understood at present, but the influence at watershed level is already of concern. Water is as important for the people in mountain communities as for those in the large urban centres, as the great majority of the mountain population is dependent on agriculture and water is only available from local sources.

A survey of current water demand and supply was conducted in the Yarsha Khola watershed in Nepal, as the first step in assessing the water situation in selected areas in the middle mountains of the Hindu Kush-Himalayas. The aim of the study was not only to assess the water need and supply situation at household level, but also to assess water problems at the watershed level. This was mainly done for the purpose of planning the activities in Phase II of PARDYP (the People and Resource Dynamics Project on Mountain Watersheds in the Hindu Kush Himalayas). In future, it is hoped that a similar study will be conducted in all the other project watersheds in order to understand the people's perception of water, and the water need and supply situation.

The Study Area and Methodology

The study was conducted in December 1998 in the Yarsha Khola watershed, which is located about 190 km east of Kathmandu along the Lamosangu-Jiri road in the middle mountains of Nepal (Figure 91). The watershed has an area of 53.4 sq.km. and an altitude range from 930 masl at the outlet in the west up to 3030 masl at Hanumante in the east. The annual rainfall in 1998 varied from 1600 mm in the lower areas to 3300 mm at the top, with a maximum during the monsoon (Merz *et al.* this volume). The watershed is dominated by agriculture with double annual crop rotations on irrigated land and single to double annual crop rotations on rain fed land (Shrestha this volume). The total population in the watershed in 1996 was estimated to be 20,620 (Shrestha 1999).

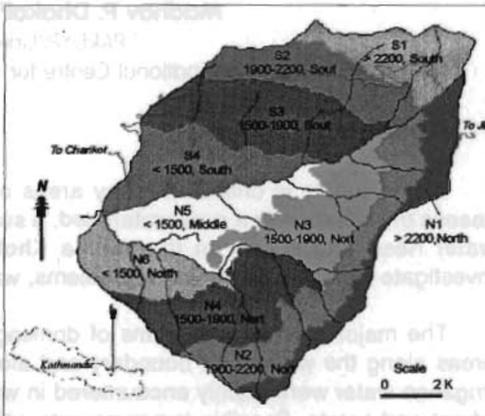

Figure 91: **Location and Layout of the Water Need and Supply Survey of the Yarsha Khola Watershed**

For this study, the watershed was divided into ten different zones on the basis of altitude and aspect because rainfall and land use alter with changing altitude and to a lesser extent aspect (Figure 91). For example, lower areas are mainly under *khet* (irrigated agricultural land) and upland areas under *bari* (rainfed agricultural land). In addition, water supply was expected to differ according to topographical location, with differences in moisture at different altitudes and aspects. Furthermore, the road leading through the watershed has had a big influence on the population pattern and problems concerned with agriculture (Brown 1998), an influence also dominated by a north/south divide.

In each of the ten zones or blocks, a number of interviews were held using a formal questionnaire in Nepali which was filled out by local enumerators trained by PARDYP. The questionnaire, one for the female and one for the male head of household, contained three parts:

- general information (female/male),
- household and animal water supply (female),
- agricultural water supply (male), and
- perception of water and water problems (female/male).

The decision to develop a separate questionnaire for women and men resulted from an RRA exercise done early in the project phase. Both this exercise and previous studies in the area showed that women farmers are responsible for work concerned with the household and animals, while men take care of some aspects of agricultural work including irrigation management. A total of 436 persons were interviewed from 218 households (218 women/ 218 men). The location of each household was marked on a 1:5,000 scale aerial photograph in order to facilitate future reassessments of the water need and supply situation.

General Assessment of Water Problems within the Watershed

The importance of water is underlined by the perceptions of the local people. 'Life' was mentioned as one word to describe water by 223 people (51%). Other words mentioned were 'soul', 'important', 'creation', and 'essential thing'. However, people also considered that there were major problems with water. Table 69 shows the amount of rainfall in the different blocks together with the perception of the residents in each block of the area as wet or dry, and the percentage of those who faced problems with water shortages. The overall number of those who faced a range of different problems with water is summarised in Figure 92.

More than 50 per cent of respondents considered the Yarsha Khola watershed to be 'dry' and only 45 per cent to be 'wet'. The perception varied with location: people generally saw the south slope, the middle part of the watershed and the lowest part of the northern slope as dry, and the upland areas of the northern slope as wet. On an annual basis, there is plenty of rainfall and the watershed can be classified as humid sub-tropical to cool temperate.

Table 69: **Annual Rainfall in 1998 and the Perception of Residents in Different Blocks**

	Block (masl)	Perception		Yes answers* to the question: 'Do you face problems with water quantity for				Rainfall	
		Dry	Wet	irrigation?'		drinking?'		Annual (mm)	Station (masl)
				No.	%	No.	%		
S1	South (>2200)	**16**	4	15	75	14	70	3316	Thuloban (2640)
S2	South (1900-2200)	38	**40**	50	63	43	54	2554	Jyamire (1950)
S3	South (1500-1900)	**33**	6	24	60	19	48	2049	Bagar (1690)
S4	South (<1500)	**39**	1	33	83	18	45	1760	Namdu (1400)
N1	North (>2200)	4	**12**	14	88	14	88	Installed in July 98	Pokhari (2260)
N2	North (1900-2200)	5	**29**	21	53	21	53	-	
N3	Middle (1500-1900)	**35**	16	35	58	23	38	Installed in June 98	Mrige (1610)
N4	North (1500-2200)	0	**60**	31	52	47	78	1847	Gairimudi (1530)
N5	Middle (<1500)	**22**	17	32	80	36	90	-	
N6	North (<1500)	**26**	9	32	78	25	63	1678	Main Hydro Station (1005)
	Total	218	194	287	70	260	63		
	No. of Respondents	412	412	412	100	412	100		

* Multiple answers possible

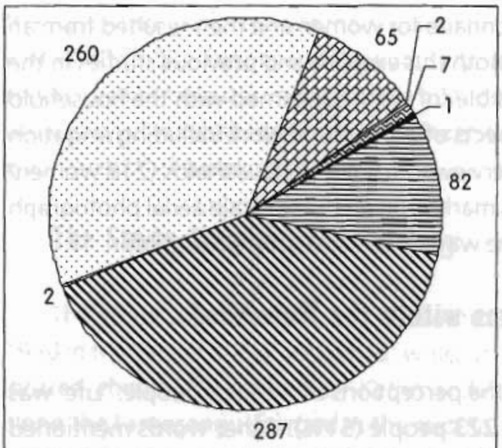

Figure 92: **Problems with Water in the Yarsha Khola Watershed**

However, the residents perception is that south facing areas with an annual rainfall of even 3,300 mm are dry as are north facing areas with an annual rainfall of 1700 mm. Thus annual rainfall alone is not a good indicator for people's perception of the relative wetness/dryness of their location.

Most of the total rainfall (more than 80 per cent on average, Merz *et al*. this volume) falls during the monsoon period. The perception of the watershed as dry is explained by answers to the question 'Do the residents face water problems?', to which 81 per cent of those interviewed answered 'yes'. The majority of those asked faced water shortages for irrigation (70%) and/or drinking (63%). Water for both drinking and irrigation was a particular concern in the upper areas of the watershed (blocks S1 and N1, see Table 69) and the middle ridge in the lower part (block N5), for drinking water on the middle northern slopes (block N4), and for irrigation in areas below 1500m (S4, N6). Drinking water quality was mentioned by 65 people (15% overall, 37% of those in the affected blocks) in the most densely populated blocks (S2, S3, and N4) which include the settlements of Mainapokhari and Gairimudi, indicating that this is also a major watershed issue. Minor problems mentioned were slumping (7 respondents) and surface erosion (2).

The number of respondents facing water shortages in different months on long-term experience is shown in Figure 93. Water shortage, both for agricultural and household supply, a big problem during the pre-monsoon period (Chaitra to Jestha, mid-March to Mid-June). Shortage of water for irrigation started in early winter and peaked in the month of Falgun (mid-February to mid-March, Figure 93), household water shortage problems arose in late winter to early pre-monsoon, and peaked in Chaitra (mid-March to mid-April). There was no water shortage during the monsoon months of Shrawan to Ashwin (mid-July to mid-October) for either households or agriculture.

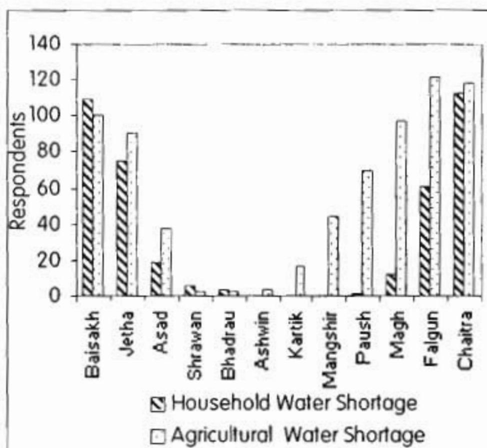

Figure 93: **Months with Water Shortage in the Yarsha Khola Watershed (total number of respondents: 218)**

Household Water Supply

Questions related to household water supply were put to female heads of household (N=218). Household water shortage was the major concern—57 per cent mentioned water scarcity, with the upper parts of the watershed facing the biggest problems. In block N1 (north facing >2200m), eight out of eight respondents mentioned water scarcity; on the high south facing slope (S1) eight out of ten (two gave no answer). However, the situation was said to have generally improved during the last five years: of a total of 218, 137 women thought household water availability had increased, 30 that availability had decreased, and 45 that there had been no change. This overall increase in water availability is believed to be the result of the installation of an extensive tap system; 84 per cent of the households interviewed obtained their water from tapped sources, which mainly belong to the communities.

However, some of these taps seem to be improperly installed, as shown by the problems indicated with the water sources (Figure 94). Contamination with sediment was mentioned by 52 people, mostly in the middle and upper parts of the watershed (S1: 40%, S3: 40%, N2: 45%, N3: 50%). Complaints of bad taste, bad quality ("people often sick"), and animal droppings reveal improper filtering and poor intake construction. Water shortage at the source was indicated by the answer "often dry" (27 people). 'Other problems' included: too far, only one tap, and pipe breakages.

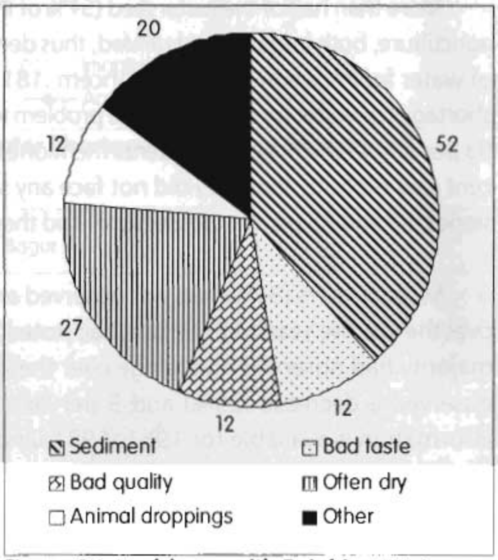

Figure 94: **Problems with Drinking Water Supply, Yarsha Khola**

The average round trip for fetching water in the watershed was 22 minutes (N=218) with a maximum of more than 60 minutes. The average time per day spent in fetching water was 109 minutes. Water is mainly fetched by the female head of household (138 cases). In 265 cases another female member of the family (daughter, mother-in-law) was said to fetch household water. Multiple answers were possible, i.e., the respondents could mention female head, daughter, and mother-in-law at the same time. Although 174 respondents said that a male member of the household, and 67 respondents that any member of the family fetched water these answers contradict the field observations, which showed mostly women queuing at the public water taps.

Each household in the watershed used 107.5 l water per day on average; or 20.6 l of water per person per day. For comparison, drinking water schemes in Nepal are designed on the basis of an average use of 45 l per person per day; this includes the Kathmandu Valley (Mr. Nani Ram Thapa, pers. comm.).

In addition to household water, each household used an average of 65.5 l/day for animals (drinking and washing). The average livestock composition per household was 1.1 buffaloes, 0.9 cows, 1.5 oxen, 3.3 goats, and 0.1 *chauri*. Most of the households in the survey (167 HH, 77%) brought the water for the animals back to the house rather than bringing the animals to the water source.

Overall, the domestic water supply situation in the Yarsha Khola watershed appears better than in many other Nepali middle mountain watersheds. The situation could be improved through work on the tap systems and source protection, but innovative strategies and techniques will be required to overcome the water shortage periods.

Agricultural Water Supply

More than half of the watershed (51% of the watershed area, Shrestha this volume) is under agriculture, both irrigated and rainfed, thus demand for agricultural water is high. However, lack of water for irrigation is a major concern: 181 male farmers out of 218 (83%) said they faced shortages of water for irrigation. The problem was most acute on the south facing slopes where 93 per cent of the male respondents mentioned shortages of water for irrigation, and only 3 per cent said explicitly that they did not face any shortage. On the middle ridge and north facing slopes, 83 and 75 per cent respectively said they faced irrigation water shortage.

Most farmers (81%) had not observed any change in the availability of irrigation water over the last five years; 17 per cent had noted a decrease and only 2 per cent an increase. The majority had observed no change over the last 25 years either (66%), although more had observed a decrease (29%) and 5 per cent had observed an increase. Historic land use information is available for 1961, 1981, and 1996. There appears to have been no major change in the amount of land under irrigation between 1981 and 1996 (PARDYP Phase I field surveys—in 1981 15 per cent of the watershed was irrigated land, in 1996 14%).

Figure 95 shows the time irrigation water was needed and the time of water shortage according to the long-term experience of the respondents. Irrigation water shortage peaked in the month of Falgun (mid-February to mid-March), when wheat and potato crops require water. The rice crop faces few if any water shortages during the monsoon season, but water shortages might be encountered during the earlier nursery and planting stages, especially if the onset of the monsoon is late.

In 1998, there were no problems for the rice crop as the monsoon arrived on time (at the beginning of Asad, around June 15th). This can be seen by comparing the 1998 irrigation calendar (Figure 95) with the climatological water balance derived for Bagar, the main meteorological station of the watershed, which is situated in the upper parts of the irrigated areas (Figure 96). However, potato and wheat crops are grown from October/November to March/April, which is the leanest period of the year in terms of water availability. If the winter rains fail, water availability is very low and farmers face a serious problem especially during Magh and Falgun.

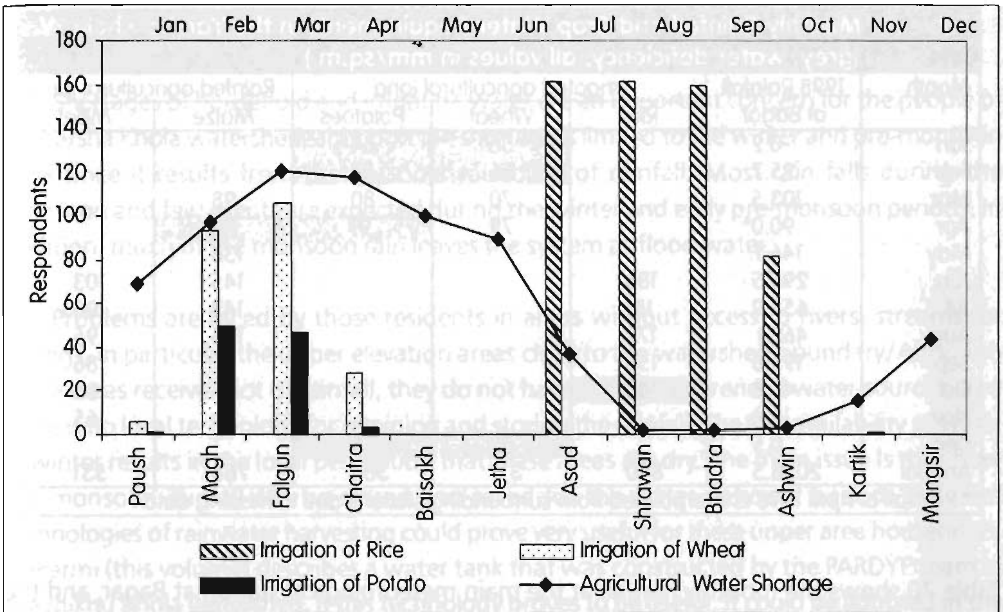

Figure 95: **Times of Irrigation and Irrigation Water Shortage (long-term experience)**

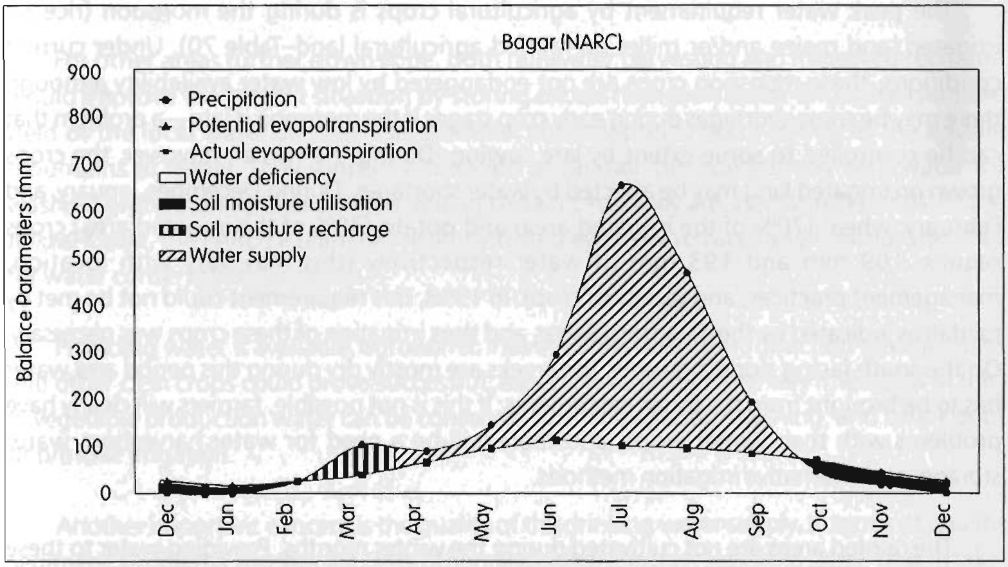

Figure 96: **Climatological Water Balance, Bagar, 1998**

The water requirements of the different crops grown in the Yarsha Khola watershed were assessed using the Blaney-Criddle method (Arora 1996). The cropping pattern was taken from previous PARDYP studies in the watershed (Brown 1998), and crop specific information from northern India (Israelsen *et al.* 1962). Only seasonal crop coefficients were used in this calculation, which results in higher than actual figures for consumption during harvesting in the case of potato and wheat. If monthly coefficients are used, these values drop somewhat.

Table 70: **Monthly Rainfall and Crop Water Requirements in the Yarsha Khola W (grey: water deficiency; all values in mm/sq.m.)**

Month	1998 Rainfall at Bagar	Irrigated agricultural land			Rainfed agricultural land	
		Rice	Wheat	Potatoes	Maize	Millet
Jan	0.2		56	64		
Feb	25.7		56	64		
Mar	103.5		70	80	98	
Apr	90.0*		79	91	112	
May	146.1				138	
Jun	295.5	186			145	103
Jul	653.9	181			142	100
Aug	462.1	172			135	95
Sep	193.8	156				86
Oct	48.8	145				80
Nov	18.4					65
Dec	0.5		57	65		
Annual	2038.5	840	317	364	768	531

* Rainfall of April 1998 is interpolated from surrounding stations due to missing data

Table 70 shows the monthly rainfall at the main meteorological station at Bagar, and the monthly crop water requirements as calculated for the Yarsha Khola watershed.

The peak water requirement by agricultural crops is during the monsoon (rice on irrigated, and maize and/or millet on rainfed agricultural land–Table 70). Under current conditions, these monsoon crops are not endangered by low water availability although there may be some shortages during early crop stages if the monsoon is late—a problem that can be controlled to some extent by late sowing. During the winter, however, the crops grown on irrigated land may be affected by water shortages. During December, January, and February, wheat (70% of the irrigated area) and potato (30% of the irrigated area) crops require 169 mm and 193 mm of water respectively (this may vary with location, management practices, and variety of crop). In 1998, this requirement could not be met by rainfall as indicated by the data from Bagar, and thus irrigation of these crops was necessary. On the south facing slope, however, the creeks are mostly dry during this period and water has to be brought from the forest catchments. If this is not possible, farmers will clearly have problems with their winter crops, and there will be a need for water harvesting, water storage, and alternative irrigation methods.

The rainfed areas are not cultivated during the winter months. Providing water to these areas during the dry periods could have a major impact on the household economy of the small farmers. Farmers said that if they had more water, or more water during normally dry periods, they would mainly be interested in vegetable production (151 in case of more water supply, 145 in case of water supply at different times, out of a total of 218), followed by fruit production. The products that were specifically mentioned were staple crops (rice, wheat), potatoes, garlic, and ginger. To date, only a few farmers store water from the monsoon period using small ponds, no other techniques were observed. The ponds did not seem to be very effective for storing water for later in the year although they may increase infiltration locally.

Discussion

Shortages of household and irrigation water are an important concern for the people of the Yarsha Khola watershed, although the shortage is limited to the winter and pre-monsoon time since it results from the seasonal variability of rainfall. Most rain falls during the monsoon and few events are expected during the winter and early pre-monsoon periods. In addition, much of the monsoon rain leaves the system as flood water.

Problems are faced by those residents in areas without access to rivers, streams, or springs, in particular the upper elevation areas close to the watershed boundary. Although these areas receive a lot of rainfall, they do not have access to perennial water sources, and there is no local technology for retaining and storing the rainfall. The low availability of water in winter results in the local perception that these areas are dry. The main issue is thus how the monsoon rainfall can be stored and saved for the water deficient period. Different technologies of rainwater harvesting could prove very useful for these upper area households. Nakarmi (this volume) describes a water tank that was constructed by the PARDYP team in the Jhikhu Khola watershed. If this technology proves to be useful, it could be adopted in the Yarsha Khola ridge areas. Other techniques are described in Dixit (1991), Agarwal *et al.* (1997), and Chalise *et al.* (in press).

For other areas further downslope, both rainwater harvesting and improved recharge would improve the current situation by storing excess monsoon water and increasing the yield of the local water sources. For example, shallow ponds occur widely in the middle mountains of Nepal. They support infiltration of rainfall, provide farmers with water for washing and watering their animals, and in certain cases they are used as fish ponds. In the Jhikhu Khola, the PARDYP team has recently tested eyebrow terraces and contour trenches for water conservation purposes.

Providing water is available, agronomic interventions like the introduction of vegetables and other cash crops could prove successful, especially as farmers are very interested in this. In vegetable production water can be conserved further by plastic mulching, and sprinkler or drip/trickle irrigation.

Another important concern is the quality of the drinking water supply. In terms of quality, sediment problems top the list, but others include improper supply system, bad intake, broken pipe system, and too few taps. There are several reasons contributing to poor water quality in the main residential areas, but mapping of point-source pollution would be necessary to enable specific causes for each problem area to be identified.

On the basis of these results, the PARDYP project is launching a major study in the field of water harvesting and water management alternatives. After the documentation of local knowledge in Nepal, and learning from other past and present projects, an extensive trial period will be initiated using different techniques as appropriate to the local conditions and as accepted by local residents. PARDYP is a regional project, so that appropriate knowledge from partner countries can be transferred easily to the watersheds in other countries and tested under the given local conditions in those watersheds. Some of the analyses of the PARDYP measurement network data from the five hydrological and eleven meteorological stations in the Yarsha Khola watershed will be directed towards a 'water for the farmer' approach. This mainly involves studies concerned with water availability, low flows, and drinking water quality. The work will be performed together with agronomists, soils specialists, and sociologists in integrated teams in order to achieve the best possible results.

For drinking water, potential collaboration is foreseen between PARDYP and relevant NGOs or government departments. It appears necessary to take a close look at the intakes of the pipe system and maintenance of the existing supply system and, as learnt from a visit to a 12-year-old drinking water scheme, the social aspect should not be forgotten. The improvements proposed by the local residents mainly cover the supply of continuous water close to their houses, in particular involving maintenance and pipe extensions.

Conclusion

The Yarsha Khola watershed has plentiful water resources but the local residents face the problem of seasonal rainfall variability, as do the great majority of watersheds in the HKH. Most of the rainfall is expected during the monsoon, and during the winter and pre-monsoon period there is not enough water for household or agricultural supply. The communities in the watershed all rely on local water sources for their daily supply. The population is increasing by 2.6 per cent annually (1971–1996), leading to intensification of agriculture and of the existing water problems. The situation, especially during the six-month dry period, ranges in different areas between critical and serious—especially in terms of development potential, labour use, and household income.

Water is not an unlimited commodity in the Yarsha Khola watershed. The following steps might help improve the water supply situation in the watershed:

- introduction of rainwater harvesting technology throughout the watershed, and especially in the ridge areas near the watershed boundary;
- introduction of storage systems for river and spring water in order to save water from the surplus period during the monsoon for the deficiency period during the dry season;
- support of measures to improve the natural recharge of springs;
- collaborative programme with drinking water groups and specialists and local women's groups in order to improve the water quality of the community tap water systems;
- agricultural investigations of alternative crop and land/water management systems under given and changing conditions; and
- technical solutions in collaboration with the local technical school in Jiri.

It is important that the social aspects are considered for any technically sound solutions identified–for example, is it acceptable, can it be managed, will the water be equitably distributed, does the initiative/innovation/technology mean more laborious drudgery (especially for women), is technical back-up available, can the technology be maintained, and is training required. Wherever financially and practically feasible, PARDYP will tackle the above problems and challenges in Phase II, which is scheduled to begin in October 1999 and run for three years and three months.

Acknowledgements

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Construction of a Water Harvesting Tank - Experience from Kubinde, in the Jhikhu Khola Watershed, Nepal

Gopal Nakarmi and Prem Neupane
PARDYP, MNR Division, ICIMOD

Abstract

Rapid growth of population in the Jhikhu Khola watershed (JKW) has been accompanied by an increasing emphasis on a cash economy as farmers focus on vegetables for the market of Kathmandu, just 90 minutes drive away. This has resulted in considerably intensified crop rotations to meet the increasing food demand at home, expanding family aspirations, and the growing need for cash to cover household expenditure. It has also led to an increased need for water in winter to irrigate the new cash crops. The available water is actually becoming less, however, as winter water is often diverted causing small feeder streams to dry up, and the ground water table is dropping as a result of increased use of pumps. Thus there is an increasing need to store monsoon water for winter production and to reconsider appropriate soil moisture conservation practices.

PARDYP team members learnt much about micro water storage tanks and underground cisterns during a visit to China. As a result a trial tank was constructed at Kubinde in the JKW. Early tests in the spring of 1999 displayed both the potential and the drawbacks. Crop trials with water stored from the monsoon season will commence in October 1999. The success of this pilot project depends upon the interested involvement of the farmers. The question remains whether even a simplified version of this tank can be afforded by the poorest farmers. Much rests on the outcome of the crop trials and the potential to organise credit facilities.

Introduction

This paper describes the results of activities undertaken in the Jhikhu Khola watershed (JKW), which lies 45 km east of Kathmandu in Kabre Palanchowk District. The JKW has a rapidly growing population and there is an increasing emphasis on the cash economy as farmers produce vegetables for the market of Kathmandu, just 90 minutes drive from the watershed. These factors have resulted in an intensified crop rotation to meet increasing food demand at home, expanding family aspirations, the growing need for cash to cover household expenditure, and the desire to make the most of the cash income opportunities in the Kathmandu markets.

Only ten to fifteen years ago, farmers in the JKW grew wheat or left their land fallow during the winter, thus water storage was not a pressing need for the dry winter months. Furthermore, most of the streams carried water all year round.

The scenario has changed dramatically in recent years. Valley floor farms are cultivated around the year, and production of high value winter cash crops has become the norm not the exception. The traditionally rainfed valley-side farms are also used for winter cultivation wherever water is available. Available winter water is now diverted and used for irrigation wherever possible, with the result that small winter feeder streams, previously providing a low flow supply, are now dry. In addition, a significant number of farmers have now invested in either diesel or kerosene water pumps, with the result that the ground water table in the watershed is under threat.

The prevalent dry winter conditions, the possibility that the erratic nature of the winter rains will intensify as a result of climate change, and the steady increase in the demand for winter irrigation, all mean that storing monsoon water for winter production is becoming a pressing need. A fresh look at appropriate soil moisture conservation practices has also become a priority. The water supply and crop water demand situation is most acute on the south facing slopes where acute winter water shortages are experienced.

PARDYP team members learnt much about micro water storage tanks and underground cisterns during visits to China over the past two years. This knowledge was applied to support experiments in the JKW. A trial tank, a conical underground cistern with a storage capacity of about 10 cu.m was constructed at Kubinde in the JKW. It lies within an area of degraded forest at present being rehabilitated by the community. Surface runoff from the 1,500 sq.m catchment area passes through five de-siltation ditches before it is collected by the underground tank. The tank was filled (overflowed) during one storm event on July 21 1999 (21 mm in 24 hour). The stored water will be used on a trial basis by a local farmer to produce cauliflower on 0.2 *ropani* (~100 sq.m.) of rainfed land during the autumn of 1999.

Site Description

Kubinde Gaun, the site of the tank, is reached from the Arniko highway (at Lamidanda) by a 3km partially dirt road through the UN army training camp followed by a 0.5 km walk which crosses the Kubinde Khola (Figure 97). The site is located on a southwest-facing valley-side slope above the cultivated valley floor at an elevation of 890m masl.

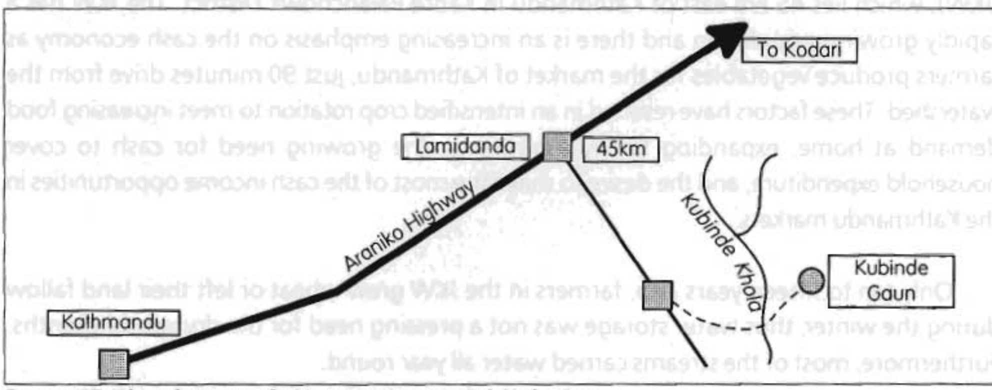

Figure 97: **Sketch Map of Site Location at Kubinde Gaun**

The site area was formally a healthy sal forest (*Shorea robusta*). In the past twenty years the forest suffered severely from overgrazing and felling. The community agreed to close the area to open grazing in 1996 and the forest is slowly recovering.

Land Use Practices

In the valley floor area below the site, rice is the main summer crop and is followed by winter wheat or potato. The fortunate farmers who have access to water, produce tomatoes and bitter gourd in small plots during the winter and spring. Water constraints generally restrict vegetable production to small plots, although all farmers in Kubinde gaun are interested in expanding their areas of vegetable.

Four of the ten households in Kubinde gaun are Thapas, two Kami, two Tamang, and one Thakuri (Table 71). The mean number of persons per household is 5.8.

Table 71: **Ethnic Composition in Kubinde Gaun**

Ethnic group	No. of Households	Total No. of Persons
Thapa	4	22 (7+6+4+5)
Malla (Thakuri)	1	5
Tamang	2	11 (8+3)
Kami	3	20 (4+9+7)
Total	10	58

The Purpose of Constructing the Underground Tank

Household water demand has increased significantly over the past two decades, but the year round supply is perceived to have diminished considerably. Records from the Horticulture Station at Panchkhal (Tamaghat) covering 27 years show that there has been no significant

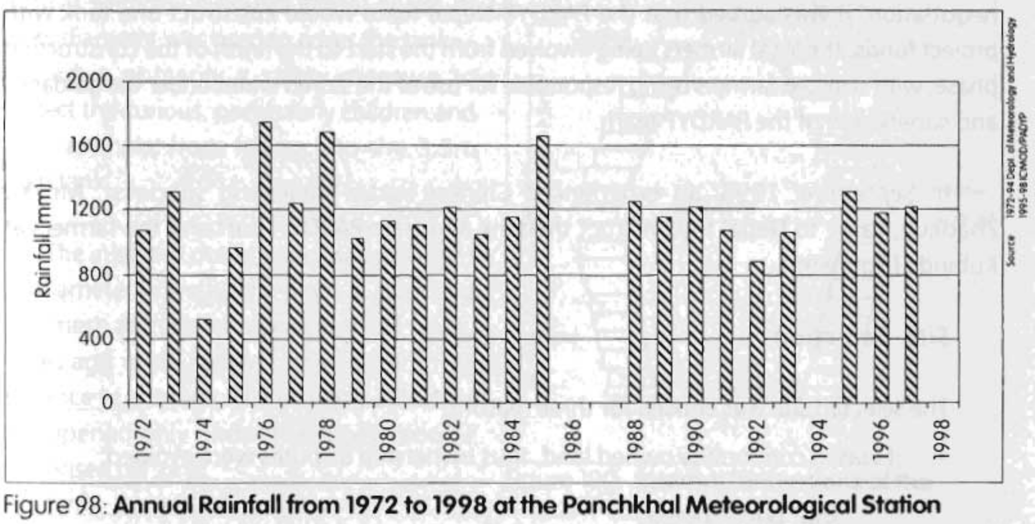

Figure 98: **Annual Rainfall from 1972 to 1998 at the Panchkhal Meteorological Station**

change in the mean annual rainfall over this time (Figure 98). The 27 year mean is 1,184 mm per year. JKW farmers frequently observe that year by year less water is available, however, and complain that this is one of their most critical current problems.

From November onwards, the flow in the Jhikhu Khola and its tributaries decreases sharply, with the result that farmers are now ponding the streams and rivers or digging wells to access the available water. All the farmers interviewed commented that winter flows are decreasing, and blame this on the extensive use of the available winter supplies. For winter crop production, farmers generally have to pump water from January onwards, primarily from pools in the main channel of the Jhikhu Khola. The number of pumps has increased dramatically within the last six years: 50 farmers are now known to own pumps. These are rented out when not in use by the owner.

The Kubinde storage tank was constructed as a response to the farmers' observations to discover whether this type of tank could help solve the problem of winter water.

The Project Approach

At 1000m elevation in the JKW, winter skies are frequently clear with the result that evaporation rates can be high and open storage tanks are not viable. Thus the Chinese type of underground conical tank was selected for the trial. This type of tank is moderately simple to construct providing there is local access to suitable rock and cement. It can be too expensive for the poorest households, but the tank size is flexible and farmers can select the volume according to their needs and the capital outlay possible.

An approximate site on the south facing slope near Kubinde village was selected as the trial area in May 1998, following discussions with the local farmers. The farmers originally had a mixed reaction; on the one hand they were suspicious about the new concept, on the other they wanted to observe and evaluate the potential of the tank. After protracted negotiation, it was agreed that the PARDYP-Nepal team would construct one tank with project funds, the local farmers being involved from the start to the finish of the construction phase, with selected farmers being responsible for use of the stored water under the guidance and supervision of the PARDYP team.

In September 1998, an experienced Chinese water-harvesting specialist, Mr. Xu Zhaokun, came to Nepal to construct the tank and train PARDYP staff and the farmers at Kubinde (Figure 99).

Site Selection

The selected site was chosen for three reasons:

- it was in community owned land, thus ownership disputes were avoided;

- it lay above the small Kubinde village and an area of agricultural land, thus permitting research and demonstration in terms of utilisation of the stored water for production of cash crops;
- it could provide water for the plantation activities related to forest rehabilitation if needed.


Figure 99: **Mr. Xu Zhaokun Advising the Nepal Team on Construction of the Water Tank**

The site was located at the foot of the degraded forest land that provided the catchment area. The slope of the area varied between 12 and 24 degrees.

Mr. Xu stressed that site stability was of primary concern, and that flat or nearly level red soil terrain and rocky areas were more stable and suitable than colluvial slopes, debris accumulations, fans, scree, or talus deposits. In addition, the storage tank should be as close to the field to be irrigated as possible with a head drop of 2-3m. The Chinese experience is that individually-owned tanks produce the best results, although that was not possible for this demonstration.

System Design

The tank was designed to have a capacity of about 10 cu.m. The limit was set by the time available, cost, and local terrain. Following advice from China, the tank was made conical or bottle-shaped, which is optimal for strength and stability. The design is shown in Figure 100. The tank was circular in a horizontal section, but dome-shaped in a vertical section. A round metal sheet of 0.7m diameter was used to cover the tank—this lid is primarily a safety measure to protect the curious, particularly children and small animals, from falling into the 3.5m deep tank.

The inlet and outlet were made of eight cm diameter polyethylene pipes. Galvanized wire mesh at the inlet pipe prevented twigs, leaves and other coarse material from free entrance to the tank. The lid was padlocked and opened only under the supervision of authorised persons.

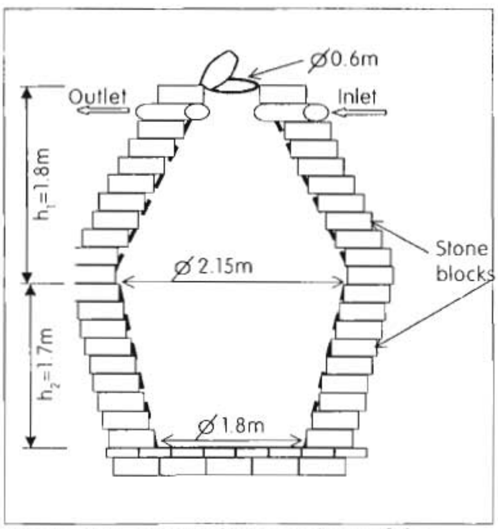

Figure 100: **Internal Dimensions of the Underground Tank**

The runoff passes through five settling ponds before it runs into the tank because the sediment output from this type of degraded red soil area can be as high as 40 t/ha (Nakarmi & Mathema this volume). One cement mortared siltation pond (1x1x1m) was constructed in front of the tank entrance and a second similar pond four metres upslope. Three temporary ponds (1x1x0.5m) were placed at strategic locations within the runoff channel system (Figure 101).

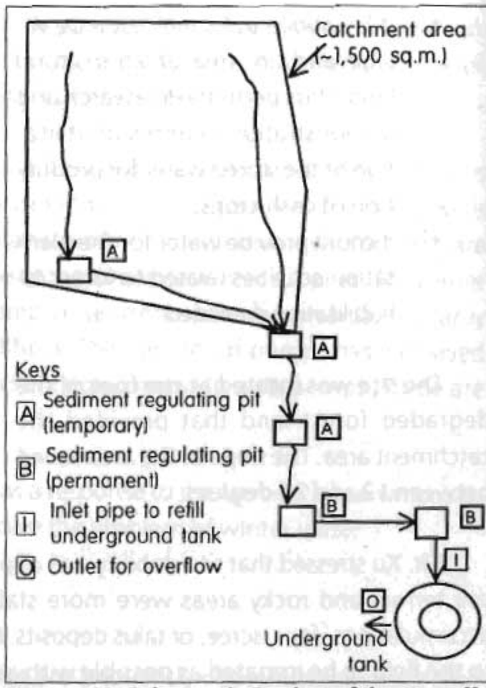

Figure 101: **Schematic Design of the Runoff Harvesting System**

Tank Construction

After the site had been identified, the centre point of the tank was located and marked on the ground. A circle of 0.8m diameter was drawn around the centre, and excavation begun vertically downward. The initial excavation of the first ½ m of red soil below the surface went smoothly, but digging out the underlying micaceous quartzite rock and rubble was time consuming and hard work. Even so, the excavation work was completed in five days by two people (Table 72).

The excavated materials were dumped near the site for later use to fill depressions. The tank walls were constructed with locally available unfaced stone using a wall thickness of generally 20 to 30cm, although in places it reached 45cm as a result of the irregular cavity shape and stone size. The stones were fixed with cement mortar. On Mr. Xu's recommendation, the weathered quartzite was crushed to a fine sand which produced a perfect cement mortar when mixed with the coarse river sand purchased from a close-by watershed. Once the rate of pay was fixed, the female farmers took the initiative to perform stone crushing, and haulage of water, cement, and sand. Almost all the inhabitants of

Table 72: **Schedule of Construction Activities from September 12-21, 1998**

Activities	12	13	14	15	16	17	18	19	20	21
Excavation	x	x	x	x	x					
Stone collection	x	x	x	x						
Stone crushing		x	x	x	x	x	x	x		
Wall construction					x	x	x	x		
Plastering								x	x	x
Fine plastering									x	x
Sand collection and transport					x		x		x	
Cement transport	x				x					
Water collection and transport						x	x	x	x	x
Siltation ditch construction									x	x
Diversion canal construction										x

Kubinde Gaun participated directly or indirectly in the tank construction, although the women were more enthusiastic and active than the men.

According to Mr Xu, it is very important to accurately control the sand/cement mixtures. Wall sections, where strength is a major concern, received a 1:6 ratio of cement to sand (Table 73), which was increased to 1:4 near the tank opening where the walls close in. A similarly strong mixture (1:4 ratio) was used to plaster the walls. The bottom of the tank was sealed with a 10 cm thick cement/sand/gravel mixture (ratio 1:3:6). Finally, a cement slurry was applied over the entire inner tank surface as a pore-sealing material.

Safety of the workers is an important concern in constructions of this sort; the tank was completed without injury—except to the project pick-up which one afternoon had all four tyres flattened by local children.

Table 73: **Proportion of Sand and Cement Used**

Type of construction	Material	Ratio
Cement mortar (for stone wall)	Cement and sand	1:6 (2 river sand+4 stone dust)
PCC bottom	Cement, sand, gravel	1:3:6
Cement mortar (wall near mouth)	Cement and sand	1:4
Wall plaster	Cement and sand	1:4
Final plastering (cement slurry)	Cement	1

Catchment Layout

The area of the catchment surface is determined by the equation:

$$A = V / (C^* R)$$

where, A = catchment area (m^2)
V = storage capacity of underground tank (m^3)
C = estimated runoff coefficient of the area
R = precipitation (m)

In this case, $V = 10\ m^3$, $C = 0.45$, and $R = 15$ mm $= 0.015$ m (precipitation during a medium rainstorm). The equation is thus $A = 10 /(0.45 * 0.015) = 1481.5$ giving a catchment area for the Kubinde tank of 1500 sq.m. The catchment area is theoretically adequate to fill the tank following one medium rainstorm, although in practice this is dependent on the intensity and duration of the rain events and antecedent soil moisture content. The calculations were based on the desire to be able to refill the tank during occasional brief storms in winter if needed, a much smaller catchment area would have sufficed to simply fill the tank during the monsoon period.

The five siltation ponds were constructed towards the bottom of the catchment area. The runoff channels were also lined with dry rock to check further erosion. The schematic layout of the catchment system is shown in Figure 101.

The Cost of Construction

The expenses incurred are shown in Table 74.

The 10 cu.m tank cost nearly NRs 25000 to build, equivalent to NRs 2.5 per litre capacity. There is considerable potential for reducing this cost, however. Almost 50 per cent of the money was spent on materials—half for cement and half for stone plus sand. Depending upon the site, sand and stone might be available locally at no charge, which would leave the cost of cement only for materials. Similarly, labour charges were also considerable as this was a research project. If labour was provided by a household or community, the costs would again be reduced. Overall, there are strong possibilities for reducing the cost of tanks of this type, especially through effective community participation.

Table 74: Cost of Construction

Item	Amount		Per Cent of Total
	NRs	US $	
Materials	12,000	175	49
Equipment	1,400	20	6
Transportation	1,000	15	4
Labour	10,000	146	41
Total	24,400	356	100

First Trials

The Traditional Winter Cropping System

The current traditional production practices for rainfed winter crops provide poor returns. A Thapa family from Kubinde Gaun provided the crop return data shown in Table 75. The choice of winter crops is very restricted because of the lack of water and the family often leave their land fallow. The return on winter cultivation with the normal selection of crops is not attractive and it is not uncommon for the crop to fail because of lack of rain.

Table 75: Economic Returns from Winter Dryland Cultivation

Expenditure			
Materials	For 6 ropani	Total expenses (NRs)	Expenses per ropani (NRs)
Chemical fertiliser	2 sacks @ 960	1920	320
Ploughing	2 Oxen @ 300	600	100
Labour	15 man days @ 100	1500	250
Total			670
Income			
Crop	Yield per ropani	Rate per unit (Nrs)	Total (per ropani)
Maize (*Zea mays*)	2 muri	500	1000
Niger (*Crizotia abyssinia* "mustard")	4 pathi	40	160
Total income per ropani			1160

Note: 1 *ropani* is approx. 500 sq.m; 1 *muri* is approx. 91 litres; 1 *pathi* is is approx. 4.6 litres

Preliminary Tests

The tank was completed in September 1998. As usual for this time of year, no substantial rain fell during the next six months, and there were also no sufficiently large winter events to fill the tank. Preliminary trials were carried out in collaboration with the Institute of Engineering, Tribhuvan University. They started in April 1999 at the end of this long dry spell using a little collected tank water augmented with water laboriously hauled from the valley bottom stream. Three farmers used the water to produce crops of tomato and capsicum, and were introduced to plastic mulching and individual plant watering. The crops took three to four months to reach maturity. The trial was not a great success, but provided some useful data and an idea of the problems to be faced during the trials to be conducted in the autumn of 1999 (Table 76). On-farm participatory trials can be difficult when new technologies and data collection are involved. (In these trials plastic mulching was used, but future trials will test alternatives like grass and straw.)

Estimated Cost/Benefit of Tomato and Capsicum Cultivation at Kubinde

Rough calculations show the following.

- One *ropani* of winter vegetables requires approximately 20,000 l of water over the growing season.
- This means a 20,000 l tank is needed for production on one *ropani* of land. The approximate cost at an appropriate location could be as little as NRs. 15,000 and a maximum of Rs.50,000, based on the costs of the trial tank and present rates.
- If tomato management and yields could be improved, a yield of 800kg/*ropani* should be possible earning a gross sum of approximately NRs.15,000 (net about NRs.13,000, taking into account the costs for fertiliser and plastic for mulching).
- This means that the cost of the 20 000 l tank could be covered in about 2 to 4 years.

Table 76: Estimated Water Requirement and Yields for Different Crops

Trial	Crop	Mulch	Water (no. of times) *	Total water per plant (l) **	Water (l) per 100 sq.m.	Water (l) per *ropani*	Trial Yield (kg per *ropani*)	Potential Yield*** (kg per *ropani*)	Gross income from trial (NRs.)
1	Tomato (*Lycopersicum esculantum*)	Yes	40	10	4,000	20,000	443	1000-1200	8495
2	Capsicum (*C. frutescens*)	Yes	40	10	4,000	20,000	250	500-800	2500
3	Tomato (*L. esculantum*)	No	40	10	4,000	20,000	200	1000-1200	2500
4	Capsicum (*C. frutescens*)	No	40	10	4,000	20,000	160	500-800	1200

* 250ml of water were provided on each of 40 occasions direct to the plant
** whether mulched or not, a total of 10 litres of water were provided to each plant during the 3-4 month cropping period
*** potential maximum yield in Nepal

- In years with reasonable winter rains, and under good management, it might be possible to produce two winter vegetable crops a year (if the tank refilled before the second crop was planted), in which case the construction of a water tank becomes a very attractive option.

These rough calculations suggest that there is potentially a real cost benefit from construction of a water tank.

Crop Water Requirement for the 1999 Trials

Various methods for calculating crop water requirements are described in Arora (1996) including the Blaney-Criddle method, the Hargreaves pan evaporation method, the Penman method, the Thorthwaite method, and the Lowry-Johnson method. Calculations for the trial were made using the Blaney-Criddle method. This empirical formula is based on mean temperatures, daytime hours, and a consumptive use coefficient. Table 77 shows the monthly values to be used in this formula.

The Blaney-Criddle formula quoted by Arora (1996) is

$$C_u = S k_i * p_i (1.8 T_i + 32)/40$$

where k_i is empirical seasonal consumptive use coefficient for the growing season
p_i is monthly percentage of daylight hours of the year
T_i is mean monthly temperature

For Kubinde, this formula gives a total water consumption for a crop grown in the autumn of about 204 mm, with a maximum in October (Table 78).

This suggests that the total water requirement under flood or furrow irrigation conditions in a 10 x 10m plot (100 sq.m) would be 100 x 0.204 cu.m or approximately 20 cu.m (20,000l). This is a high requirement, thus the planned PARDYP cropping trial will investigate

Table 77: **Monthly Temperature, Percentage of Daylight Hours, and Consumptive Use Factor for Vegetables**

Month	Oct	Nov	Dec	Source
Mean monthly temperature (°C) (T_i)	22.2	17.7	13.7	HMG/N (1990)
Monthly percentage of day-time hours (pl)	8.09	7.40	7.42	Arora (1996, Table 20.2, p.711)
Monthly consumptive use crop coefficient (k_i)	0.6	0.55	0.50	Michael (1978, Table 7.8, p 524)

Table 78: **Estimated Consumptive Use of Water by a Vegetable Crop (mm)**

Month	October	November	December	Total
Consumptive use of water	87	65	52	204

crop development using plant by plant irrigation with the rows of plants under plastic mulch. Water will be applied to each plant through a hole in the plastic mulch using a watering can—it is estimated that this will save some 66 per cent of calculated water, so that the water requirement would be 6 cu.m (6000l) per 100 sq.m or 30 cu.m per *ropani*.

Horticulturalists at HMG Department of Agriculture suggested that 500 cauliflower plants can be grown in a 100 sq.m plot. The estimated 6000 l of water required would provide one litre of water per plant per week for 12 weeks. The Kubinde tank can provide this even if there is no rain or runoff during the three month crop production period, but if these calculations are correct a tank twice or three times as large would be required to successfully irrigate one *ropani* (500 sq.m) of winter vegetables if there is no rain during the cropping period.

The actual water requirement may be less than the calculations suggest. Badhani (1998) claimed that in Nainital, UP, India, some different vegetables were grown successfully using 15-22 applications of 0.25 litre of water per plant (3.75 to 5.5 l) over the cropping period (of 3 months). Even the higher figure implies the application of only 2,750 litres to 500 plants or 14,000 l per *ropani* if the plants are planted at a density of 500 plants per 100 sq.m.

These estimates range widely, and clearly well managed trials are required to answer the question of crop water requirement in systems where plants are mulched and individually watered. The water requirement has a direct bearing on the cost/benefit analysis of tank construction, so that the planned trials are considered extremely important.

The crop trial with a three-month cauliflower variety is planned for October 1999. Water will be delivered from the tank to the field via a pipe and the participating farmer/s will measure and record the time taken and volume of water applied to each plant on each occasion. Great care will be taken during the application of water to the plants. The capital outlay is high, and the field management operations are time and labour consuming, so that only a good return on the crop will persuade farmers that water storage for winter irrigation is worthwhile.

Conclusion and Recommendations

An underground water tank with a capacity of 10 cu.m and catchment area of 1500 sq.m was constructed in 10 days in September 1998, at a cost of Rs.25,000 (US$365 equivalent). It was designed to fill during one rainfall event of 15 mm on moist soil.

Five open settling ponds were constructed to trap sediment. An eight-centimetre diameter polyethylene pipe diverts water from the last pond into the tank.

Local farmers were generally sceptical and only partially convinced of the potential economic return accruing from the construction of the tank. Women were more optimistic than the men and carried out most of the labouring work. The PARDYP project bore the cost of the tank construction as a research and demonstration site. Early tests in the spring of 1999 showed both the potential and the drawbacks. Crop trials with water stored from the monsoon season will commence in October 1999.

The success of this pilot project depends heavily upon the involvement and interest of the farmers, and the question remains of whether even a simplified and cheaper version of this tank can be afforded by the poorest farmers. Much rests on the outcome of the crop trials, and later on the potential to organise credit facilities.

The shortage of water faced by farmers in the Jhikhu Khola is considered to be symptomatic of a larger picture that is evolving in the mountains of the region—the need for winter water in order to capitalise on higher market prices. The potential of stored water to assist in raising household incomes and standards of living is unquestioned, and this research trial hopes to answer some of the key questions, for example: can the majority of farmers afford such a tank; how can construction costs be lowered; what is the cost/benefit relationship; and what in-field management technologies are appropriate, affordable and applicable?

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Part Four

Geology and Soils

The Geology of the Xizhuang Watershed, near Baoshan, West Yunnan

Yang Yongping[1], Liu Raoli[2], Xu Jianchu[1]
[1]Kunming Institute of Botany, Chinese Academy of Sciences
[2]Baoshan Prefecture Academy for Investigation and Design of Water Conservancy and Hydroelectric Power

Abstract

The Xizhuang watershed is geologically complex. It comprises a tectonic ring structure integrated in the Qinghai-Tibet-Yunnan-Burma-India-Nepal longitude-parallel tectonic belt. A series of intricate faults and folds contribute to the landform and landscape development within the watershed. The rock formations belong to the Upper Cambrian, the Ordovician, and the Quaternary lithostratigraphy; carbonate rocks make up 40 per cent of all the bedrock in the watershed. As a result of a series of tectonic movements, fault activities, and the formation of rock cracks, this watershed is rich in underground aquifers and springs. To date, seven underground rivers and seventeen major springs have been identified. Nine of these springs were discovered during the geological survey carried out by PARDYP, the results of which are reported here. The survey also showed that except for one spring (No. 16, whose water supply is unclear), almost all the underground water supplies originate from within the Xizhuang watershed. The influence of the rocks on soil formation, the occurrence of landslides and erosion instabilities, and effective measures to control geological hazards are also described.

Introduction

The Xizhuang watershed is located in the northwest of Banqiao Township, Baoshan City, extending from 99° 06′ to 99°13′ E and 25°13′ to 25°17′ N. Within this watershed, there are three administrative villages: Xizhuang, Qingshui, and Lijiasi. The Xizhuang River originates from the mountain ridge in Yiwanshui. There are two tributaries in the upper reaches of the watershed: the Lijiasi River to the east and the Shenjia River to the west. They converge near Qingshui Village. In the lower reaches, the Xizhuang River flows into the Donghe River, which finally joins the Nujiang (Salween) River System—the system that drains the entire Baoshan Basin.

In order to understand the key features of geology, tectonics and lithosphere, and terrain stability, a preliminary geological survey was undertaken in the watershed in 1997. There are many springs in this watershed, and this raises questions about the geological origin of the water and how to arrive at water balance calculations for the watershed. The purpose of the survey was to identify the geological influence on the hydrological cycle, to describe the movement of the underground water through the geological formations, and to determine the influence of the bedrock on soil formation and terrain stability.

Lithostratigraphy

The Xizhuang watershed is in the southern part of the Hengduan Mountains, and is traditionally considered to be composed of two main tectonic elements, the so called Qinghai-Tibet-Yunnan-Burma-India-Nepal tectonics and longitude-parallel tectonics. These tectonics are extremely complex with intricate faults and many incomplete folds. The three different tectonic structures that occur in the watershed include the Qinghải-Tibet-Yunnan-Burma-India-Nepal tectonics, the longitude-parallel tectonics, and the ring-like tectonics.

The tectonic movement in this watershed has two characteristics: an interval and unconformable movement of the crust and the successive activities of faults. The formation of valley terraces and the development of gullies and caves are influenced by the uplift and downthrust movement of the crust. For example, there are a series of pebbly-mud stone successions in the west banks of both the Lijiasi River and the Qingshui River located 10 to 20 metres above the riverbeds, whereas some caves like the Shihua and Tiger caves are observed along the riverbanks. In general, the left bank of the river is the uplift region and the right side is the decline region. Overall, the western margin of the Baoshan Basin (including the Xizhuang watershed) is a region of uplift, while the eastern margin is in an area of downfaulting. This is responsible for the eastern flow direction of the stream and the creation of the asymmetrical landform. Tectonic activity along the main faults has resulted in frequent earthquakes leading to the formation of fault basins during the Cenozoic era.

The field survey showed that the stratigraphy is well developed and falls within the Paleozoic, Mesozoic, and Proterozoic stratigraphic periods. The lithostratigrapic outcrops in this region are shown in Table 79. Three geological transect profiles were made through the watershed.

Underground Water

The water-containing rocks are mainly intercalated and banded carbonate and clastic rocks of Paleozoic origin. As a result of successive tectonic movements, small cracks have occurred in these rocks. This watershed is a typical result of the longitude-parallel tectonics contained within the overall ring tectonics. These ring tectonics result in the development of tectonic cracks of which the radial distribution of cracks near Shuangmaidi is an example. The result is that more of the rain falling in higher elevation areas seeps into the ground through the cracks between rocks.

The watershed is located on a major fault zone. The fault zone has relatively flat rock layers made up of conglomerates, which encourages water to seep underground. For example, a series of spring outcrops occur in the Qingshui river along this fault line. The discharge from these springs generally varies from 20 to 30 l/s, but in the largest spring (No. 17) the discharge reaches 277 l/s. The regional tectonic and lithographic characteristics determine the stream flow, the aquifers, and the occurrence of springs.

Table 79: The lithography of Xizhuang Watershed

Era	Period	Epoch	Formation	Symbol	Thickness (m)	Description of lithography
Cenozoic	Quaternary	Holocene		Q_h^{d+pl}	0.5-20	Alluvium, flood; sand, conglomerate, and rudaceous soil; HCO_3-Ca.Mg water
				$Q_h^{'d+el}$	0.5-15	Slope and vestige sediments; rudaceous and sandy soil
		Pleistocene		Q_p	0-665	Alluvium and lake sediments; soil with sand and conglomerate
Lower Paleozoic	Ordovician	Middle	Shidian	O_2S	100-464	Sandstone, shale, slates; HCO_3-Ca water
		Lower	Laojianshan	O_1^3	743	Purple and greyish-green shale intercalated sandstone
			Mantang	O_1^2	404	Grey-white quartz sandstone, sandstone
			Yanqing	O_1^1	450	Grey-white quartz sandstone intercalated limestone, shale
	Cambrian	Upper	Upper Baoshan	ϵ_3^{3-3}	308-800	Grey-green shale intercalated sandstone, mud-banded limestone, and fish-egg-like limestone
			Lower Baoshan	ϵ_3^{3-1}	890	Siltstone, shale intercalated mud-banded limestone
			Upper Shahechang	ϵ_3^{3-1}	218	Shale, siltstone
			Lower Shahechang	ϵ_3^{2-3}	286	Upper is fish-egg-like limestone, lower is shale intercalated limestone
			Upper Hetaoping	ϵ_3^{2-2b}	300	Upper is limestone and fish-egg-like limestone, lower is shale and slate
			Lower Hetaoping	ϵ_3^{2-2a}	500	Shale, sandstone, phyllite
			Shuangmaidi	ϵ_3^{2-1}	750	Phyllite, slate, sandstone

Notes on the Lithography

Upper Cambrian (ϵ_3)	The base contains deposits of clastic rocks intercalated with carbonate of presumed shallow marine origin. The lithographic elements consist mainly of yellow and grey-yellow sandstone, siltstone, shale, and greyish and grey medium to thick laminate mud-banded limestone, fish-egg-like limestone, and mud limestone, which are intercalated alternately in different thicknesses. The total thickness ranges from 610 to 2,973 metres. This type is mostly distributed in the central and southern parts of the watershed.
Ordovician (O)	This was basically built up through shallow marine deposits, and the lithography is usually variable. Clastic rock intercalated with carbonate is the major element. This type is mainly distributed in the northern part of watershed.
Quaternary (Q)	This was formed through a series of alluvial, flood, and sedimentary activities and is mainly composed of sand, conglomerate, and soil. This type occurs in the riverbed and on some mountain slopes.

Table 80: **The Characteristics of the Underground Rivers in the Xizhuang Watershed**

No.	Water supply region	Catchment area (sq. km.)	Stream length (km)	Lithostratigraphy	Relevant spring no(s).	Discharge (l/s)
1	Yiwanshui to Shuangmaidi	6.5	4.0	Developing along fault belt, limestone	S2, S3, S4	60.6
2	Baiyan'ao to Zhangjiawan	6.0	3.5	Developing along laminate limestone	S6	50
3	the Pass of Houzilu to Langmaidi	4.0	2.5	Developing along fault belt	S10	20
4	Da'aozi to Qingshui River	6.5	4	Intercalated limestone and sandstone	S12	51.5
5	Sange'naozi to Lengshuiqing	6.0	2.5	Along fault belt	S14	25.2
6	Houpo to Xiangcao'ao	6.5	4.0	Intercalated limestone and shale	S16	55
7	Whole watershed	32	12	Along fault belt	S17	262.3

Note: Underground river No.7 receives all the underground water in the watershed. The discharge was measured as 276.8 l/s in April 1979, and as 490 l/s in February 1997.

Seven underground rivers have so far been identified in this watershed from the field observations and surveys (Table 80). These rivers are described below.

- No. 1. This underground river is 4 kilometres long, has a catchment area of approximately 6.5 sq.km., and is located near the Yiwanshui and Shuangmaidi villages. The river develops and extends along a fault in a northwest direction. The southern part of the fault is composed of Upper Cambrian limestone intercalated with shale and sandstone and receives water from many sources. The northern side consists of Middle and Lower Ordovician sandstone and shale, which can stop the water from flowing into other regions. As a result of this, the ground water flow along the fault belt is generally poor. Only three springs, Nos. 2, 3, and 4 were found in this belt. The total discharge of these three springs is more than 60.6 l/s.
- No. 2. This river section is about 4 km long. The water-supply area is situated near the Baiyan'ao and Zhangjiawan villages. The catchment area is 6 sq.km. Banded limestone rocks belonging to the Upper Cambrian period are the source of many aquifers. The shale at the river bottom prevents water from seeping further into the rock formation. The discharge of spring No.6, found along this river, is 50 l/s.
- No. 3. This river section is also about 4 km long. The water supply catchment area is 6.5 sq. km and stretches from Houzilu pass (Monkey Road) to Langmaidi. The main rocks consist of Cambrian mud-banded limestone and intercalated lutites. The spring from this river outcrops near the Qingshui Primary School and discharges 51.5 l/s of water.
- No. 4. This underground river is 4km long and has a catchment area of 6.5 sq.km. The water supply area is near the Da'aozi and Qingshui Rivers, and originates from intercalated limestones and sandstones.
- No. 5. This river is 2.5 km long, and the catchment area covers 6.0 sq.km. It is located between Sange'naozi (Three Brains) and Lengshuiqing hamlets, and

comprises an underground water supply that converges along a fault belt, and runs in a north-west to north-easterly direction. Upper Cambrian limestone and shale are the dominant bedrock. The outcrop of this river is exposed in the upper reach of Lengshuiqing stream (1975 masl) and discharges at 25.2 l/s in spring No.14.

- **No. 6**. The water supply of this river has not been determined and is likely to originate from an adjacent watershed. The outcrop of the river is near the watershed divide, and the spring discharge (No. 16) is about 55 l/s.
- **No. 7**. This river is 12 km long, with a catchment area of 32 sq. km. Its spring is located near the Tiger Cave (1740 masl). The discharge was 277 l/s in April 1979, and 490l/s in February 1997; the latter measurement was made by the Baoshan Hydrological Station.

So far the PARDYP team has identified more than 200 springs in the watershed between Tiger Cave and Lijiasi, seventeen with a discharge of more than one l/s. The highest spring was found at 2425 masl, the lowest near Tiger Cave at 1740 masl. During the 1997 fieldwork, nine new springs with a discharge of more than 1l/s were discovered with a total discharge of 191.9 l/s. Previous investigations had only recorded eight springs of more than one l/s. If spring No.17 is excluded, the total discharge is 372 l/s. The details of the springs with a discharge of more than one litre are shown in Table 81.

The challenge is to understand the water balance in the watershed and the contribution and behaviour of these springs and their discharges. For example, is the spring water in Tiger Cave from this watershed or supplied from other watersheds? Spring No. 16 is at an elevation of 1975 metres. As this is nearly as high as the watershed divide (2075m) the discharge of 55 l/s from this spring probably comes at least partly from another watershed. Thus it is quite possible that a small amount of the water in spring No. 17 comes from other watersheds since it accepts all Xizhuang underground water.

Main Soil Types

The formation of soil is correlated with base rock characteristics. In the Xizhuang watershed, carbonate and clastic rocks are dominant although metamorphism has taken place in the lithography as a result of successive tectonic movements. In general, the red soils and yellow-red soils have developed from mud-banded limestone, limestone, and mud limestone, and the brown and red-brown soils from sandstone, shale, and phyllite. The soil types in the watershed can also be classified by elevation (Table 82).

The thickness of the soils varies with the soil type and the location in the watershed. On gentle slopes, mountain bottoms, and the river valley, the soil is relatively deep, for example, the soil of the left river bank of the Shuangmaidi is 10 to 15m thick, and in the basin area and Lijiawan and Zhangjiawan hamlets, 5 to 10m thick. In contrast, on steep mountain slopes and near limestone outcrops soil depth can be as little as 0.5 to 3m.

Table 81: **The Main Springs along the Fault Belt in the Xizhuang Watershed**

No.	Locality	Altitude (m)	Litho-stratigraphy	Type	Tectonic structure	Geomorphology	Discharge (l/s)
*S1	Damaidi (SW)	2215	$\in^{3}_{3\text{-}2}$	decline spring	fault belt (EW)	cross of two valleys	8
S2	Damaidi (SE)	2100	$\in^{3}_{3\text{-}1}$	decline	fault complex (NW and NE)	mountain bottom near highway	34.6
*S3	Damaidi (SE)	2090	$\in^{3}_{3\text{-}1}$	decline	fault complex	mountain bottom near highway	16
*S4	Damaidi (SE)	2089	$\in^{3}_{3\text{-}1}$	decline	fault complex	mountain bottom near highway	10
S5	Lijiasi (N)	1980	$\in^{3}_{3\text{-}2}$	decline	fault complex	left side of river bed	29.8
*S6	Zhangjiawan (N)	2045	$\in^{3}_{3\text{-}2}$	decline	fault complex	slope bottom	50
*S7	Wangjiawan (SE)	1975	$\in^{3}_{2\text{-}2b}$	decline	fault complex	in river valley	5
*S8	the middle reach of Shui'ao river	2125	$\in^{3}_{2\text{-}2a}$	decline	fault complex	left side of river valley	15
S9	the middle reach of Longziqing river	2195	$\in^{3}_{2\text{-}2a}$	decline	fault belt (NE)	cross of two valleys	19
*S10	Langmaidi Primary School	2000	$\in^{3}_{2\text{-}3}$	decline	fault belt (NE)	cross of two valleys	20
S11	Shihua Cave	1930	$\in^{3}_{2\text{-}2a}$	decline	fault belt (NE)	left side of river bed	1.0
S12	Qingshui Primary School	1875	$\in^{3}_{3\text{-}1}$	uplift	fault complex (NW and NE)	basin margin	51.5
S13	Lengshuiqing behind Yinjia Settlement	1870	$\in^{3}_{3\text{-}2}$	decline	fault complex	left side of valley	19.5
S14	Lengshuiqing behind Yinjia Settlement	1975	$\in^{3}_{2\text{-}3}$	decline	fault complex	right side of valley	25.2
*S15	opposite Dajiayan	1850	$\in^{3}_{3\text{-}1}$	decline	fault belt (EW)	mountain bottom	12
*S16	upper reach of Heyuan'ao	1975	$\in^{3}_{3\text{-}2b}$	decline	fault complex (NE and NW)	two sides of valley	55
+S17	Tiger Cave	1740	$\in^{3}$	decline	fault complex	river bed	276.8

Note: * Springs discovered during the fieldwork in February 1997. Total discharge of the nine newly identified springs is 191.9 l/s.
+ Spring No. 17 receives all the underground water in the Xizhuang watershed. The discharge was measured as 276.7 l/s in April 1979, and as 490 l/s in February 1997.

Table 82: **Dominant Soil Groups According to Elevation**				
Elevation	Soil Colour	Soil Structure	Fertility Status	Water holding capacity
Above 2600m	Brown	Good	Good	High
2000-2600 m	Red-Brown	Poor	Acidic, low P & K	Poor
Below 2600 m	Yellow-Red or Red	Adequate	Acidic, moderate	Poor - Moderate
Paddy soils	Usually Grey	Good	Fertile	High

Geological Hazards

Natural instabilities and degradation processes induced by human activities cause environmental hazards. Landslides, mudflows, slope failures, and terrace collapses commonly create problems for the local inhabitants through road damage, erosion along riverbanks, flooding, and slope failures. These affect crop production and interrupt market and transport activities. As a result of active tectonic movement, the metamorphic lithography, and the distribution of faults, landslides are a frequent phenomenon on the steep slopes, especially on the eastern side of the Lijiasi River. The field observations identified twelve sites where landslide risk is high. The largest landslide observed was approximately 200m wide and 80m long; its depth was approximately 5m, and its total sediment source was estimated at 175,900 cu.m. In most cases, landslides occur in areas dominated by sandstone and shale formations (Table 83).

Table 83: **Landslide Statistics from the Xizhuang Watershed**							
No.	Length (m)	Width (m)	Average Thickness (m)	Area (sq.m)	Volume (cu.m)	Activity	Location
H1	32.5	150	12	5,000	3,600	Continuous, active	Damaidi
H2	40	150	7	6,000	4,200	Continuous, active	Longziqing River
H3	25	60	2	1,500	3,000	Tentative, stable	Lijiasi River
H4	25	200	3	5,000	15,000	Tentative, stable	Lijiasi River
H5	30	60	4	1,800	7,200	Tentative, stable	Lijiasi River
H6	10	15	2	150	300	Continuous, active	Damaidi
H7	20	70	3	1,400	4,200	Continuous, active	Lijiasi River
H8	30	80	5	2,400	12,000	Continuous, active	Lijiasi River
H9	30	50	6	1,500	9,000	Continuous, active	Lijiasi River
H10	30	35	5	1,750	8,750	Continuous, active	Lijiasi River
H11	80	60	5	4,800	24,000	Continuous, active	Behind Yinjia
H12	60	80	3	4,800	14,400	Continuous, active	Dajiayan
Total	412.5	1,010	-	36,100	175,850	-	-

The formation of gullies is mostly correlated with tectonic movements. Like landslides, most gullies are found near mountain slopes and adjacent to river valleys. In the Xizhuang watershed, there are fourteen areas that are heavily gullied. They are typically 200 to 300m long, 30 to 40m wide, and 8 to 10m deep (Table 84). Mudflows usually occur infrequently because the vegetation cover is generally well developed. Two mudflow sites were identified during the fieldwork. One was located at the end of the Heyuan'ao valley, and was 40m wide and 150m long with an estimated sediment source of 48,000cu.m; the other was at the end of a side valley to the right of Tiger Cave and had a fan-shaped sediment source 180m long and 50m wide with an estimated volume of more than 90,000cu. m.

Table 84: The Active Gullies in the Xizhuang Watershed							
Gully No.	Length (m)	Width (m)	Area (sq.m)	Depth (m)	Type	Category of activity	Location
Hd1	380	50	19000	20	"U"	medium	Damaidi
Hd2	280	15	4200	5	"U"	strong	Damaidi
Hd3	220	25	5500	10	"U"	strong	Damaidi
Hd4	130	70	9100	10	"U"	strong	Jizipo
Hd5	370	15	5500	3	"V"	tentative stable	Zhangjiawopo
Hd6	300	40	1200	15	"U"	medium	Yinjia
Hd7	150	40	6000	10	"U"	strong	Yinjia
Hd8	300	30	9000	8	"U"	strong	
Hd9	250	30	7500	8	"U"	strong	Lengshuiqing
Hd10	140	20	2800	4	"V"	tentative stable	Luojiadi
Hd11	150	20	3000	5	"U"	strong	
Hd12	150	30	4500	101	"U"	strong	Dajiayan
Hd13	1000	40	40000	10	"U"	strong	Dajiayan
Hd14	200	20	4000	8	"U"	strong	Xiaoshanpo
Total	4020	445	131,300	-			

Landslides and gullies cause serious damage to the local environment and the properties of the residents, while mudflows are less important as they are less common and less extensive. To control these environmental hazards, long-term strategies are needed to protect existing vegetation and promote reforestation and rehabilitation. In some areas with high landslide potential (such as the right side of the Lijiasi River, where there is an existing landslide already 1-2 km long), the risk of crop and land damage is high and some engineering construction will be necessary to prevent further damage from future slides.

Conclusions

The geology in the Xizhuang watershed is dominated by limestone and metamorphic rocks of the Upper Cambrian, Ordovician, and Quaternary ages. The area is tectonically active as is evident from the series of faults that have shaped the landforms in the watershed. The limestone formations create difficulties in establishing a water balance for the watershed since streams disappear underground in many places. There are also a very large number of springs, suggesting the presence of many aquifers and underground rivers. So far some 21 potential aquifers have been identified. It appears that the majority of the spring water originates from within the watershed, but additional research is needed to identify the source of some of the springs. A survey of existing springs and a tracing of water sources should be considered important research tasks since water shortages are common during the dry season in the lower lying areas of the watershed. Terrain instabilities were observed in those areas where the slopes are steep and tectonic activity is greatest.

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Geological Mapping and Its Importance for Construction Material, Water Chemistry, and Terrain Stability in the Jhikhu and Yarsha Khola Watersheds

Gopal Nakarmi
PARDYP-MNR Division, International Centre for Integrated Mountain Development

Abstract

Geological studies were conducted in the Jhikhu (JKW) and Yarsha Khola watersheds (YKW) to document the rock types and their role in agricultural and rural industrial activities. Field investigation revealed that quartzite, limestone, selected bands of sandstone, and marble are quarried at different locations for short periods of time in the JKW, whereas quartzite, some gneiss and to a lesser extent black slate are currently excavated in the YKW. In both watersheds, local residents are currently mining primarily for local consumption.

In the JKW, water draining the quartzite and sandstone contained fewer soluble minerals and had low average runoff conductivity values (50 and 75 µS/cm, respectively). Soils derived from these rocks had a low cation exchange capacity and are thus highly sensitive to acidification. In contrast, carbonate rocks such as marble, limestone, and dolomite contributed the highest quantities of water-soluble minerals, and had higher conductivity values (average 375 µS/cm). The soils formed from these rocks contained higher levels of cations, and thus have a greater capacity to buffer acidic conditions.

Using GIS overlay and query techniques, a composite map was generated of vulnerable units in geology, surficial material, elevation, slope, aspect, and land use. This map can be considered as a map of potential instability; areas at risk had the same configuration as the currently unstable areas. All the areas of potential risk (620 ha)—the degraded areas—were concentrated at sites where all the critical geological, topographical, and land use factors were dominant.

Introduction

Understanding of rock types and their role in agricultural and rural industrial activities is important for the economic growth of mountain communities in both the Jhikhu and Yarsha Khola watersheds. As well as being a key local building resource, competent rocks also modify the quantity and quality of water that passes through them, have a direct influence on soil fertility, and play a key role in terrain stability.

Geological surveys were undertaken in early 1997 and 1998 in the Jhikhu and Yarsha Khola watersheds in order to map the spatial distribution of the major rock formations . The rock types were identified, the attitudes of bedding plane recorded, and prominent structural features traced. Of the eight formations identified in the Jhikhu Khola watershed (JKW), only sandstone, quartzite, limestone, and marble are selectively mined for local use. Five geological formations were identified in the Yarsha Khola watershed (YKW), and of these only two, quartzite and some black slate, are currently quarried by local farmers. Stone products are mostly sold only locally.

Carbonate rock influences the runoff conductivity of water and affects its pH. The amount of cations present in the soils developed from these rocks is high compared to those in soils from schist and gneiss.

Stability was also investigated. The rocks near the Mahabharat thrust in the JKW are heavily folded and crushed and thus form a fragile belt prone to landslides. In contrast, the synclinal fold stretching from Ghoredhunga to Mirge in the YKW displays a stable landform with well-developed thick red soils on top.

Site Location and Methodology

The Sites

The locations of the two watersheds studied are shown in Figure 102. The JKW covers 11,100 ha, has an elevation range from 800 to 2,100m, is situated 45 km east of Kathmandu, and is accessible via the Arniko highway. Fifty-five per cent of the JKW is currently under agriculture, with about two-thirds rainfed land and one-third under irrigation. The YKW covers about 5,300 ha, has an elevation range from 1000m to 3000m, is located 190 km north-east of Kathmandu, and is accessible via the Lamusangu-Jiri highway. Fourteen per cent of the watershed is irrigated agricultural land and 37 per cent rainfed agricultural land. The main difference between the watersheds is the distance to market—the JKW is in close proximity to markets and has undergone more rapid agricultural intensification and population growth than the YKW. Table 85 shows the increase in the number of houses during the period 1990 to 1996 (JKW) and 1961 to 1996 (YKW).

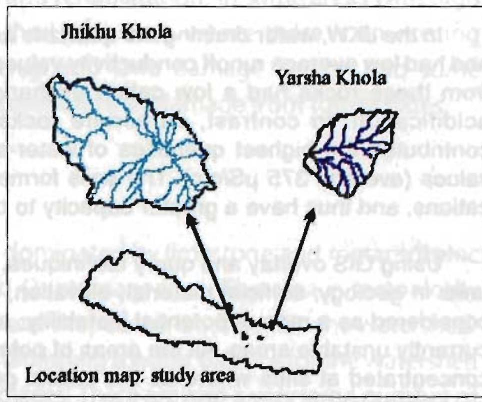

Figure 102: **Location of the Jhikhu Khola and Yarsha Khola watersheds**

Stones are the largest visible natural resource in Nepal (UNDP 1977). Increasing house construction activities in both watersheds demand appreciable quantities of stone. The production and utilisation of stones is labour intensive, but if properly managed can have a significant impact on the local economy.

Table 85: **Increase in the Number of Houses in the Two Watersheds**			
Watershed	1961	1990	1996
Jhikhu Khola	No data	5474*	8002*
Yarsha Khola	285**	No data	3640**
Sources: *Shrestha 1998; **Jordan and Shrestha 1998			

Methodology

Conspicuous bedding planes and prominent structural features were provisionally identified on aerial photographs (scale 1:25,000) and verified in the field. During field surveys, 750 sites with rock exposures were examined in the JKW and 500 sites in the YKW. The attitude of the bedding plane, the nature of contact between beds, the structural features, and the rock types were recorded on a 1:25,000 scale topographic map.

The chemistry of rainwater changes while moving through rocks that contain soluble minerals. Runoff conductivity is often a good natural indicator of the quality of the rock formation spread in the vicinity. A conductivity meter and pH probe were used to examine the chemical condition of stream and spring water during low flow conditions, when rock-water interactions are most pronounced.

Stream flows were measured at sub-watershed outlets in the JKW during the dry period when the chemical contribution from the rocks to the water flow is high. Observation points were marked on the topographic map, as were major geomorphic features of instability like landslides, gullies, rills, and bank erosion.

All existing degraded areas including landslides, gullies, rills, and eroding stream banks were provisionally identified on aerial photographs, and then verified and cross-checked in the field. A geomorphic process map was thus created and then digitised into a GIS; previously digitised information on elevation, geology, surficial material, and land use maps assisted in the analysis.

The following were identified using GIS overlay and query techniques: the most dominant elements in topography (including elevation, slope, and aspect); geology (encompassing lithology and surficial material); and the relationship between land use category and instability. A composite map was produced which showed areas at the highest risk of instability (Nakarmi 1996).

Results

Geology and Building Material

The JKW

Two geological domains were identified in the JKW. The upper domain belongs to the Lower Kathmandu Complex and overlays the lower domain, which is part of the Upper Nuwakot Complex. These domains are separated by the regional tectonic plane known as the

Mahabharat Thrust (Stöcklin and Bhattaria 1981). Six lithological formations belonging to the Lower Kathmandu Complex are characterised by, from top to bottom, meta-sandstone, schist and quartzite intercalation, mica schist, quartzite, marble, and garnetiferous mica schist. The dominant rocks underlying the Upper Nuwakot Complex are a dark grey slate, intensively folded green schist, grey phyllite, limestone, and dolomitic limestone (Figure 103).

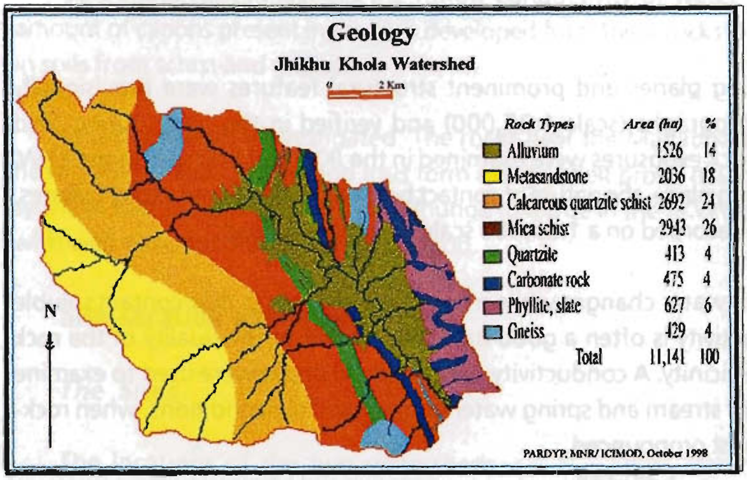

Figure 103: **Geological Map of the Jhikhu Khola Watershed**

The slate and limestone near the thrust plane are intensively crushed and several landslides are active particularly near the south-east corner. These rocks are considered to be from the Paleozoic period while the Lower Kathmandu Complex belongs to the Precambrian to early Paleozoic period. The predominant bedrock alignment is in the NW-SE direction with moderate to steep dips towards the south-west.

Quartzite, limestone, selected bands of sandstone and marble are quarried at different locations for short periods of time mainly for local consumption in the JKW, which is undergoing rapid development in terms of house and road construction. The present demand for stones as a major construction material is huge. As a result of the lack of any clear policy on stone excavation, quarries start and shut down over periods of a few weeks or a month creating frequent shortages, especially in seasons when house and road construction take place (autumn and winter).

Unfortunately for many, stones of acceptable quality and quantity are often located in the forested areas that are managed by communities, and under the present arrangements only community members have access to such rocks which cannot be sold to outsiders. Non-members of these fortunate communities must look for other sources. Currently, river channels are the easiest alternative, but such practices are leading to a rapid depletion of stones along the Jhikhu Khola and its tributaries. This has caused a three-fold problem:

- the stones required for repairing the weirs that frequently break during major storms are no longer available and stones for this purpose have to be transported into the watershed from outside;

- river scouring and bank cutting processes are intensified and the most productive lands adjacent to the river channels are more frequently damaged and sometimes destroyed; and
- serious environmental problems result that are threatening the aquatic biota.

A clear-cut policy is needed on stone excavation because the competent rocks suitable for construction are scarce and without a proper excavation policy many local residents do not have access to these vital resources. Community groups need to be more involved in environmental protection activities, including afforestation of quarries after completion of excavation activities. This will reduce the pressure on the river channel.

The YKW

The geological materials of the YKW consist of low to medium grade metamorphic rocks. Graphitic schist and dark slate form the core of the synclinal fold, the axis of which stretches from the main hydrological station towards Mirge, gently dipping east. Black schist is underlain by a succession of talc, magnesite, and medium to thickly bedded quartzite, which is intercalated with grey schist. Although the quartzite bed generally forms narrow bands, its exposure widens around Khaniyachaur, north-west of Thulichaur and Yarsha (Figure 104). Green phyllite and chlorite schist underlay the quartzite bed. Below these rocks is gneiss, which occupies the base of the geological section in the YKW. Gneiss (31%) and phyllite (19%) are widely exposed on both flanks of the syncline. An anticlinal axis passes through Dahaltar and Khaniyachaur where thickly bedded quartzite forms the core of the anticline. Quartzite, some gneiss, and to a lesser extent black slate are currently mined by the residents in YKW, primarily for local use.

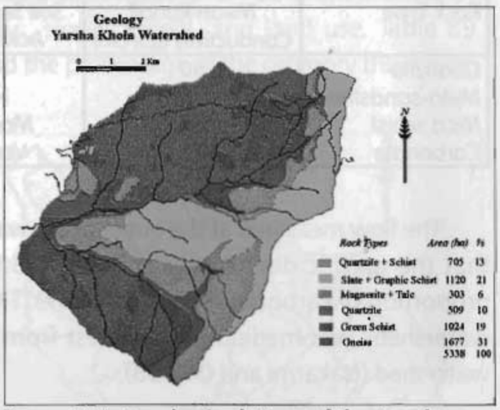

Figure 104: **Geological Map of the Yarsha Khola Watershed**

Proper support guided by clear policies for stone quarry management will enhance the capacity of the local community to develop these resources for economic development. A road link to the quarry site might lead to significant economic development in the north-east block of the YKW.

Geology versus Water Chemistry

Water chemistry surveys were conducted during the dry season when the influence of rocks on water flowing through them is most marked. The electrical conductivity of water is a good indicator of the quality and type of the bedrock, with carbonate rocks giving very high values and quartzite generally low values.

The JKW

Water draining the quartzite and sandstone contained fewer soluble minerals and had average conductivity values of 50 and 75 μS/cm respectively (Table 86). Similarly, the soils derived from these rocks had a low cation exchange capacity and are consequently highly sensitive to acidification. Carbonate rocks such as marble, limestone, and dolomite contributed the highest quantities of water-soluble minerals: water draining these rocks had higher conductivity values averaging 375 μS/cm. The soils formed from these rocks had higher levels of cations, and thus have a greater capacity to buffer acidic conditions. The runoff conductivity of water from mica schist terrain was moderate and the soil derived from these rocks was moderately sensitive to acidification.

Table 86: **Rock, Water, and Nutrient Status in the Jhikhu Khola Watershed**

Rock Type	Mean Runoff Conductivity (μS/cm)	Soil Sensitivity to Acidification	Soil Cation Level	No. of Soil Samples Analysed
Quartzite	50	High	Low	23
Meta-sandstone	75	High	Low	17
Mica schist	157	Moderate	Medium	13
Carbonate	375	Very low	High	8

The flow measured at the outlet of subwatersheds in the JKW during dry periods showed that the specific discharge was highest (3.5 l/min/ha) from the area containing a large proportion of carbonate rocks (Table 87). The discharge from sandstone-dominated sub-watersheds was medium, and lowest from the mica schist and phyllite-dominated sub-watershed (Nakarmi and Li 1998).

Table 87: **Water Flow Conditions by Major Rock Types in the Jhikhu Khola Watershed**

Mean Specific Discharge (l/min/ha)	Dominant Bed Rock Type in the Sub-watershed	Number of Observations
3.5	Carbonate rock	2
1.7	Sandstone	4
0.3	Mica Schist + Phyllite	12

The YKW

The influence of rocks on water was also clearly visible in the YKW. There are few water-soluble minerals in gneissic rocks, and the runoff water from these rocks had the lowest conductance (average 32 μS/cm) and a mean pH of 7.1 (Table 88). The soils generated from these rocks were poor in cations and are thus highly susceptible to acidification. Runoff water from the schist and quartzite rocks (with mica partings) had moderate conductivity values and the amount of cations in the soils from these rocks was moderate. Magnesite, dolomite, and limestone release bicarbonate and carbonate, as a result the runoff water was harder and had a high conductivity (387 μS/cm) and high pH (8.3). The amount of cations in the soils from these rocks was much higher, which makes them less vulnerable to acidification. Both carbonate rocks themselves, and the water released from these rocks, can be used to amend soil acidity.

Table 88: **Rock – Water – Nutrient Status in the Yarsha Khola Watershed**

Rock Type	Mean Runoff Conductivity (μS/cm)	Average pH	Soil Sensitivity to Acidification	Soil Cation Level	Number of Soil Samples
Magnesite + Talc	387	8.3	Very low	High	5
Quartzite + Schist	189	8.2	Low	Moderately High	19
Slate + Graphitic Schist	167	7.9	Low	Moderately High	13
Quartzite	124	7.7	High	Low	9
Green Schist	112	7.5	High	Low	22
Gneiss	32	7.1	High	Low	42

Geology versus Terrain Stability

In order to identify the most vulnerable areas in the JKW, a geomorphic process map depicting all existing degraded areas was overlaid with maps of six different themes or categories: geology, surficial material, elevation, slope, aspect, and land use. Table 89 indicates the vulnerable units in each category and the percentage of the category they cover.

A second GIS overlay and query were performed on vulnerable units in geology, surficial material, elevation, slope, aspect, and land use without the map of currently unstable sites. The composite map (Figure 105) can be considered as a map of potential instability, since it shows areas with the same configuration as the currently unstable areas. This map shows that the degraded areas, which comprised 139 ha or 22 per cent of the total 620 ha area of potential risk, were located at sites where all the critical geological, topographical, and land use factors were present.

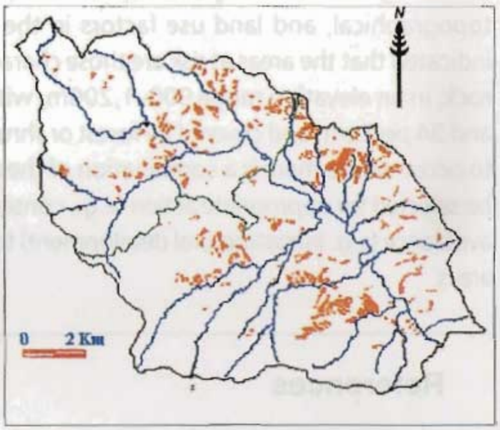

Figure 105: **Potentially Unstable Sites**

Degraded lands are generally left unattended. Figure 105 shows the areas where rehabilitation activities need to be carried out. It is clear that infrastructure development activities should be avoided at such sites.

Table 89: **Vulnerable Units in Each Category in the Jhikhu Khola Watershed**

Category	Vulnerable Units	Percent Within Each Category
Geology (bed rock)	schistose quartzite + mica schist	64
Surficial material	residual soil + rock	90
Elevation range (m)	900-1199	71
Slope (%)	5–34	50
Aspect	south + east	64
Land use	forest, shrub +others	77

Conclusion

Excavation of competent rocks is the backbone of residential and infrastructural development in the JKW and the YKW. However, a clear policy is needed for stone excavation activities to systematise quarry operations. This policy should ensure a regular and adequate supply of appropriate construction materials for a greater number of people. This would relieve pressure on the boulders in the riverbeds, which are essential to protect the channel and for repairing the diversion structures that frequently break during flood events.

Carbonate rocks released a greater proportion of soluble mineral into the draining water than quartzite and schist. The runoff conductivity of the water draining carbonate terrain was high, with a mean of 375 μS/cm. In contrast, the runoff water from quartzite had a low cation content resulting in low conductivity values (less than 50 μS/cm). The runoff conductivity measured in streams during low flow conditions was a useful descriptor of bedrock conditions and gave a good indication of the resilience of soil against acidification.

Using the GIS overlay technique, it was possible to determine the dominant geological, topographical, and land use factors in the currently degraded areas of JKW. This work indicated that the areas at risk are those characterised by mica schist and schistosed quartzite rock, in an elevation range 900–1,200m, with a south or east aspect, on slopes between 5 and 34 per cent, and covered by forest or shrub land. The greatest risk of degradation is likely to occur where there is a combination of these factors. These results enable priority areas to be selected for appropriate action (e.g., conservation, change of land use or management) or avoidance (e.g. infrastructural development) to prevent further degradation in the most prone areas.

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The Soils of the Xizhuang Watershed, Baoshan, China

Sha Liqing[1], Qiu Xuezhong[1], Gan Jianmin[1], Xu Jianchu[2], Ai Xihui[2], Gao Fu[2]
[1]Kunming Division, Xishuangbanna Tropical Botanical Garden, CAS, Kunming 650223, China
[2]Kunming Institute of Botany, CAS, Kunming 650204, China

Abstract

Preliminary results from soil studies conducted in 1997 and 1998 show that the soils of the Xizhuang watershed, near Baoshan, are generally poor in available phosphorus, have a low pH range, and are deficient in exchangeable cations. Only the soils originating from limestone have adequate pH and cation concentrations. The organic carbon content is generally higher than in most other Himalayan watersheds; the presence of limestone and the effect of elevation are the key factors responsible for conserving soil carbon concentrations. A brief description of the biophysical setting is provided and the key factors that influence soil fertility—elevation, parent materials, and land use—are identified.

Introduction

Soils are one of the most valuable natural resources in the world but insufficient attention is being placed on them both globally and in China. Soils are under stress as a result of rapidly expanding populations, particularly in China where the arable soil resources are limited, population densities are high, the expansion of urban centres into the best agricultural land is rapid, and inputs and cropping intensities are often excessive. The unreasonable use of soils will quickly exhaust soil fertility.

Soil degradation is of concern in China because of agricultural intensification, agricultural expansion into marginal lands, deforestation, overgrazing, atmospheric pollution, and poor management. Mountain watersheds are particularly sensitive to degradation because of the steep topography, relatively young and poorly developed soils, and accelerated hydrological processes. Slope failures, soil erosion, deterioration of soil nutrients, and downstream effects such as flooding and sedimentation will increase rapidly under inappropriate land uses. Hence, if we hope to achieve sustainable management of resources overall, special attention should be paid to the management of soil resources in the mountains.

The overall goal of the People and Resource Dynamics Project (PARDYP) is to improve understanding of the environmental and socioeconomic processes that lead to soil degradation, to develop land use management practices that prevent degradation, and to promote rehabilitation techniques in those areas where degradation has already occurred. To be successful, techniques need to be adapted to the prevailing environmental conditions, and acceptable to the stakeholders in terms of productivity, profitability, time, labour, and input requirements.

PARDYP selected the Xizhuang watershed in Yunnan Province as a study site to gain a better understanding of the relationships between sustainable soil use, degradation, and socioeconomic impacts and constraints. A series of research projects was carried out between June 1997 and February 1998 to determine the soil fertility status in Xizhuang watershed, to identify the key issues that need to be addressed, to measure the rates of change in soil quality, to develop options to reduce degradation, and to promote techniques that restore soil productivity.

Methods

Data Collection

Socioeconomic, climatic, hydrological, geological, land use and vegetation, and sociocultural data were collected in the watershed. Maps, aerial photographs, PRA surveys, field surveys, and laboratory analysis were used.

Survey and Sampling

Several transects were selected based on the land use, elevation, soil type, and parent material and a detailed soil survey carried out along each. Soil samples were collected at a depth of 0-20 cm at places representing each major combination of these factors. The locations of the sites were drawn on a topographic map for subsequent incorporation into a GIS system and the samples were analysed in the laboratory.

Soil Analysis

The following soil parameters were determined in the laboratory: pH; organic carbon; total nitrogen; available nitrogen; available phosphorus; exchangeable Ca, Mg, K, Na; exchangeable Al; cation exchange capacity; and base saturation. The methods used to determine these parameters are described in Liu *et al*. (1996).

Soil Mapping

A GPS (global positioning system) unit was used to generate the site co-ordinates in the field and the site information was transferred to an ARC/INFO GIS database for spatial analysis. Aerial photos, topographic maps, geological maps, and field observations served as the basis for selecting appropriate sampling sites and delineating land forms.

Results and Discussion

The Biophysical Setting of Xizhuang Watershed

Climate—Three distinct climatic zones were identified based on elevation, air temperature, and rainfall distribution: the north subtropical zone, the south temperate zone, and the temperate zone. These zones can also be identified in the watershed by vegetation zonations.

Geology—The geology is described in more detail in Yang, Liu and Xu in this volume. The dominant parent materials of the watershed soils are: Quaternary alluvial deposits; Ordovician sandstone, shale, quartzite, and sandy slate; and Cambrian carbonate rock, sandstone, and shale.

Water System—The Xizhuang River originates in the Yiwanshui mountians, the highest area of the Xizhuang watershed. The stream system runs in a north-easterly direction into the Baoshan Basin. The main tributaries are the Lijiahe and Qingshuihe rivers. As a result of the predominance of limestone rock, the stream channels disappear in many places to form underground rivers, thus many springs originate in the watershed.

Vegetation—Natural forests have almost all disappeared in the watershed and many have been replaced in recent decades by pine plantations, mainly dominated by *Pinus armandi* and *Pinus yunnanensis*. *Cunninghamia lanceolata* and *Alnus nepalensis* have also been planted in a number of places since the 1950s. Deforestation has been extensive in the past leading to soil erosion, landslides, and degraded areas.

Land Use—In the low and flat areas along streams, especially where irrigation is available, the lands are used primarily for rice, wheat, maize, and potato production. The staple crops (like maize) and tea are mainly grown in areas below 2,200m. Only potatoes and buckwheat are grown above 2,200m. Forests cover almost all the areas above 2,200m, and grazing land has almost totally disappeared from the watershed.

Soil Type—The soils in the Xizhuang watershed were classified into five types according to the Soil Classification System of Yunnan Province (Soil Survey Office of Yunnan Province 1980, 1996) (Table 90). These were:

- paddy soils, which are located in the lowest portion of the watershed;
- soils developed on recently accumulated alluvium, which are distributed along the rivers and streams (irrigation is available in most of these areas and the dominant land use is arable crop production—wheat, maize, potatoes, and vegetables);
- red soils, which occur below 2200 masl (these are the most widely distributed soils in the watershed and are mainly used for agriculture with commercial crops like tea and pine plantations dominating);
- yellow-brown soils, which are mainly found between 2200-2600 masl (forests cover most of these areas but some potato and buckwheat are also grown); and
- brown soils, which are located above 2600m and are almost exclusively under forest cover.

Table 90: **Soil Types and Their Area in the Xizhuang Watershed**

Soil Type	Area (ha)	Per Cent
Paddy soils	6	0.2
Recently accumulated soils	113	3.3
Red soils	1425	41.2
Yellow-brown soils	1353	39.1
Brown soils	559	16.2

Soil Fertility

Table 91 summarises the basic soil fertility parameters for the whole watershed. The soils are generally very acidic and lack basic nutrients such as available phosphorus and exchangeable cations. The nutrient status is highly variable within the watershed, but generally the soil organic carbon content and the base saturation values are quite high compared to those in other watersheds in the Himalayan region. The presence of limestone rock clearly plays a significant role in this.

Table 91: **Soil Fertility Status in the Xizhuang Watershed**

Characteristic	Range	Mean	Standard Deviation
pH	3.67 - 6.77	4.42	0.53
Organic C (%)	0.595 - 11.396	3.435	2.140
Total N (%)	0.071 - 0.786	0.271	0.147
Available N (mg/kg)	37.8 – 651.7	239.0	130.4
Available P (mg/kg)	0.4 - 97.1	4.6	13.3
Exch. Ca (cmol/kg)	0.042 - 16.411	2.194	2.606
Exch. Mg (cmol/kg)	0.115 - 1.667	0.557	0.405
CEC (cmol/kg)	3.063 - 17.475	6.583	2.761
Base saturation (%)	4.15 - 99.44	49.95	30.00

Differences in Soil Fertility by Soil Type, Elevation, and Parent Material

As paddy soils occupied only a very small area of the watershed, they are not discussed further in this paper. Table 92 shows the soil fertility parameters for the different soil types (apart from paddy soils). There were significant differences in fertility between the soil types. The yellow-brown and brown soils were more acidic and had higher organic C, total N, and available N values than the other two types of soil. The parent material and the elevation effects are considered to be the main reasons for these differences.

The relationship between certain soil fertility parameters and elevation and aspect are shown in Table 93. The soil organic carbon increased with elevation, which indicates that in the higher elevation soils the accumulation of litter was greater than the decomposition of organic matter. This is the result of the cooler conditions at higher elevations. Carbon influences the cation exchange capacity (CEC) so the CEC values also increased with elevation

Table 92: **Fertility of Different Soils**

Characteristic	Recently Accumulated Soil	Red Soil	Yellow-brown Soil	Brown Soil
pH	4.86	4.44	4.33	4.00
Organic C (%)	2.324	2.687	4.956	7.509
Total N (%)	0.208	0.221	0.370	0.538
Available N (mg/kg)	223.3	191.7	324.7	479.7
Available P (mg/kg)	21.7	2.1	1.4	2.2
Exch. Ca (cmol/kg)	4.054	2.371	0.625	1.827
Exch. Mg (cmol/kg)	0.840	0.571	0.250	0.707
CEC (cmol/kg)	6.495	5.966	6.103	11.847
Base saturation (%)	80.93	53.3	30.2	30.4

(Table 93). The soil acidity increased with elevation as a result of the higher precipitation, which results in higher leaching rates for base cations such as Mg, and a lower percentage base saturation.

Table 93: **The Relationship between Soil Fertility and Elevation and Aspect**

Characteristic	<2200m South (n=31)	<2200m North (n=26)	>2200m South (n=8)	>2200m North (n=13)
Org. C (%)	3.863	3.991	7.447	5.761
Exch. Mg (cmol/kg)	0.484	0.621	0.423	0.573
CEC (cmol/kg)	6.898	6.603	10.536	7.843
Base saturation (%)	44.5	43.8	25.7	38.2

Figure 106 shows the relationship between parent material and soil fertility. The parent material had a significant effect, particularly when comparing the soils formed on limestone rocks with those originating from quartzite and sandstone. Soils on limestone had higher pH, higher available P, and higher exchangeable Ca than did those on sandstone.

The cation exchange capacity was particularly low in soils at lower elevations and in the red and yellow brown soils. The CEC could be improved by increasing the application rates of organic matter to these soils.

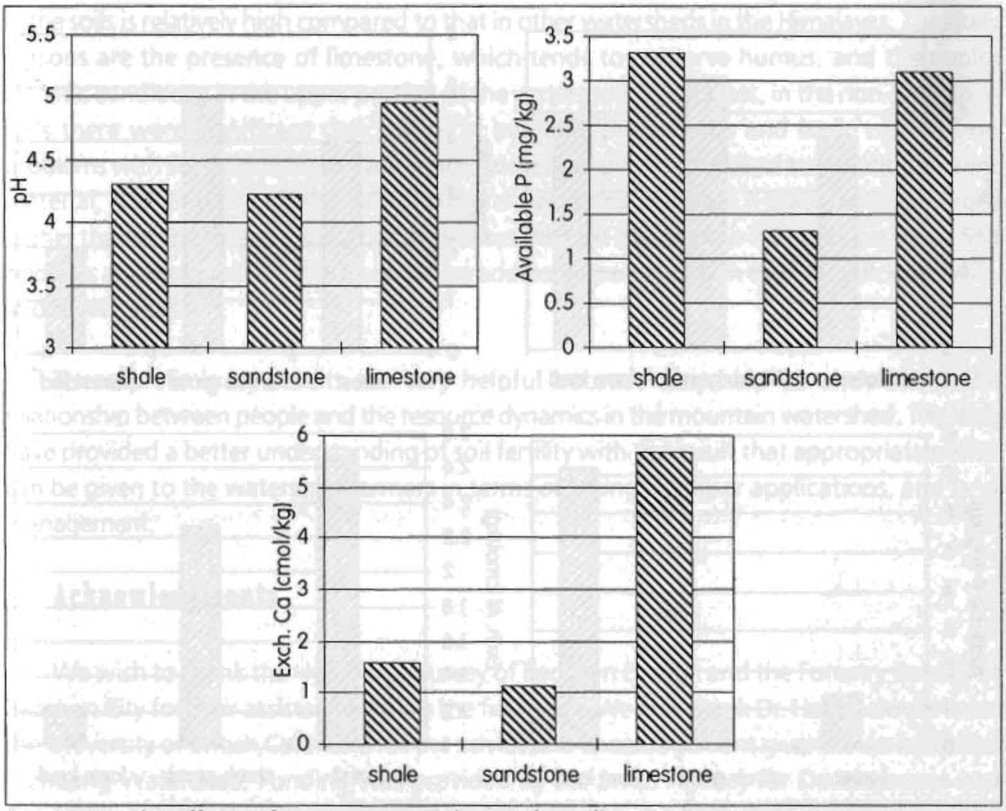

Figure 106: **The Effects of Parent Material on Soil Fertility**

Land Use Effects on Soil Fertility

The effect of land use on soil fertility is shown in Figure 107. Soils under forest and shrub grass vegetation generally had higher organic C and exchangeable Al than those in cultivated farmland. The available P was generally higher in farmland than in forest or shrub land. This may be due to a combination of factors: the difference in acidity, the lower exchangeable Al content (caused by the reduction in acidity), and the higher inputs of manure and fertiliser into the agricultural areas.

Human activities have both positive and negative effects on soil fertility. Agricultural intensification through multiple crop rotations and intercropping enables farmers to increase biomass production but also requires significantly higher inputs. As long as organic matter and chemical fertiliser inputs are maintained at the same level as removal by the crop and losses due to leaching and erosion, such systems can be sustained. The maintenance of organic carbon through applications of both animal manure and composted vegetation is of particular importance because of its influence on the physical properties of the soil (soil structure and hydrological properties) and its importance for microbial activity.

Maintaining the soil pH within the optimum range of 5.5-6.5 is also critical for the availability of both macro and micro-nutrients. Application of lime is only needed in those

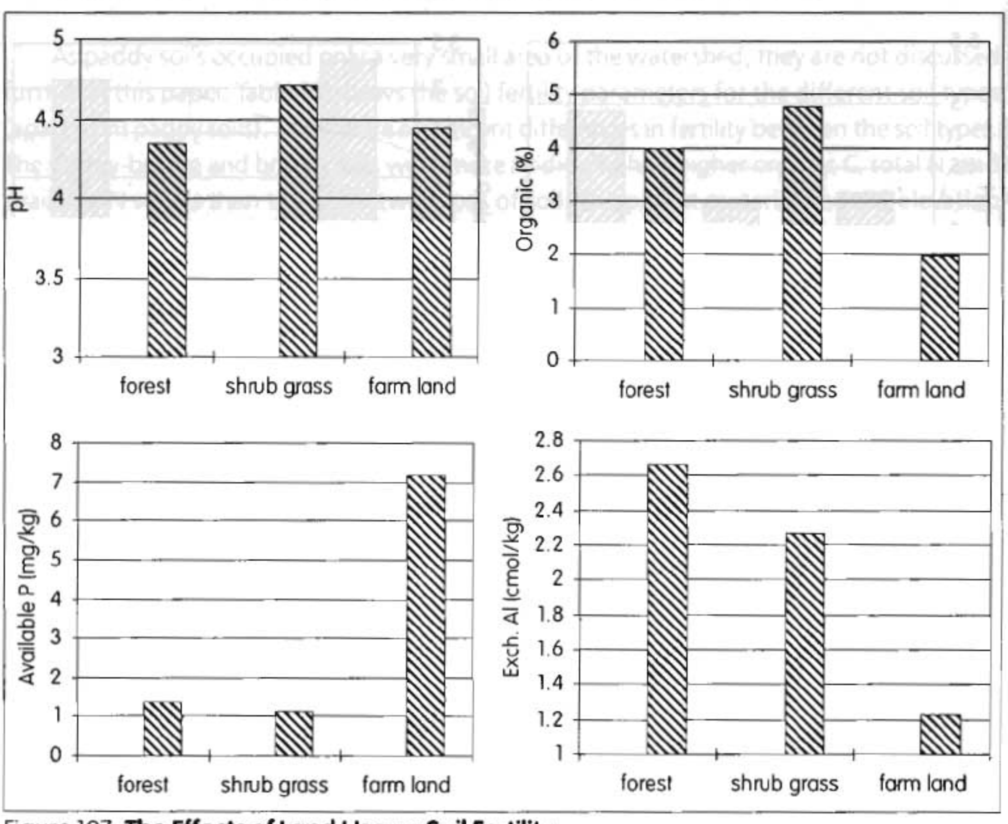

Figure 107: **The Effects of Land Use on Soil Fertility**

soils that have an undesirably acidic pH and that are deficient in base cations. Some of the red, yellow-brown, and brown soils fall into this category. The old and highly leached red soils which have very low pH and high Fe and Al content are particularly problematic because they usually have high P-sorption capacity and therefore restrict phosphorus availability to plants; in addition at a pH below 4.0 they often create Al toxicity.

Soil Stability and Erosion Prevention

Terrain instabilities lead to erosion, affect soil fertility, and influence flooding and sedimentation downstream. Soil stabilisation is an important part of the project and biological erosion control measures have been initiated using nitrogen fixing trees and grasses, as well as low nutrient demanding and drought resistant species. The following N-fixing species have been planted to stabilise the soils: *Acacia* sp., *Tephrosia* sp., *Albizzia* sp., *Maorotrilium macropurpureum*, *Crotalaria mucronata, Cajanus cajan,* and *Vicia villose.* At the same time *Juglans sigillata,* and *Morus alba* have been interplanted with corn and wheat as a soil protection measure.

Conclusions

The preliminary results of the research on soils indicate that the organic carbon content in the soils is relatively high compared to that in other watersheds in the Himalayas. The likely reasons are the presence of limestone, which tends to conserve humus, and the cooler climatic conditions in the upper portion of the watershed. In contrast, in the non-limestone soils there were significant deficiencies in available phosphorus and basic cations and problems with soil acidification. Differences were also identified related to elevation, parent material, and land use effects. In agricultural fields, the available P-levels were generally higher than in the forested soils, but in all cases they fell into the low P-fertility category. Soil acidity is another problem that needs to be addressed particularly in the red, yellow-brown, and brown soils.

These preliminary results are very helpful because they help us understand the relationship between people and the resource dynamics in the mountain watershed. The data have provided a better understanding of soil fertility with the result that appropriate advice can be given to the watershed farmers in terms of liming, fertiliser applications, and land management.

Acknowledgments

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Plant-microbial Community Dynamics Associated with Soil Nutrient Gradients in Newly Rehabilitated Degraded Land

A Case Study from the Indian Central Himalayas

Sanjeev K. Bhuchar, Sudhir S. Bisht, Basant K. Joshi, Bhagwati P. Kothyari and Bhupendra S. Bisht
GB Pant Institute of Himalayan Environment and Development, Katarmal, 263 643, Almora.

Abstract

In the mid-hills of the Indian Central Himalayas, there is paucity of information about the biophysical rates of recovery when degraded areas are rehabilitated. This study presents an analysis of change in terms of floral communities and associated change in soil character within an area of land under rehabilitation that was used extensively for grazing in prior times. During the last six years (1993-98), factors related to the Importance Value Index (IVI) of plant species, the densities of various microbial organisms, and the soil character were measured with a view to recording rates of improvement in soil fertility, colonisation of comparatively useful species, and biomass.

Introduction

The most spatially and economically important human uses of land include cultivation in various forms, livestock grazing, settlement and construction, reserves and protected lands, and timber extraction. These and other land uses have cumulatively transformed land cover on a global scale (Turner *et al.* 1994). Destruction of forests for agricultural expansion to support a growing human population has been prevalent in the Hindu-Kush mountain ecosystems (Rawat *et al.* 1997). Many of these cleared areas revert to secondary ecosystems when left abandoned. Such lands are centres of evolution for many grasses, herbs, and microbes, and because they have developed into important and influential ecosystems, it is useful to have quantitative and qualitative information about them. Much contemporary research in the central Himalayan mid-mountains focuses on understanding of how the nutrient cycles of different ecosystems respond to environmental disturbances, but there is a paucity of studies on biodiversity, ecological dominance, and the physiological responses of floral communities within degraded areas. It is well known that disturbances in any stable ecosystem have a negative effect on the entire biome, and that soil characteristics are immediately affected. The loss of closed forest canopy results in the exposure of soils, and as a result the organic matter they contain becomes vulnerable to oxidation. When subjected to uncontrolled grazing these areas undergo a series of modifications as a result of the loss of the insulating effect from vegetation, an altered moisture infiltration rate, and soil nutrient losses. Subsequently, floral communities develop that are characterised by strategies that enable them to survive and produce seed. The present study focuses on the changes in floral communities and soil characteristics over a period of six years within a rehabilitated area previously degraded by overuse and overgrazing.

Study Site

The study site, called Balgara, has a total area of nine hectares, and is located in Arah village, which lies in the Indian central Himalayan mid mountains, between 29° 59'30" and 29° 59'56" N and 79°35'20" and 79°36'15" E. The region as a whole is characterised by a variety of microclimates, mainly governed by geographical coordinates and altitudinal variations. The study site faces NE and lies at an altitude of 1490 masl. The temperature drops to just 0°C during winter and reaches a maximum of 37°C during summer. The area receives moderate precipitation (mean annual value 1,380 mm).

Site History

- Until 1950—under forest dominated by *Pinus roxburghii*
- During the 1960s—site cleared for agricultural activities
- Until 1975—agriculture practised, partially under irrigation
- After 1975—area abandoned as a result of fragmentation of land holdings, distant location from the main village of Arah, increase of out-migration of males, a scarcity of water for irrigation, and destruction of crops by monkeys; became an open grazing area
- 1993-1996—area selected for a rehabilitation project funded by IDRC; the concept of land consolidation and community management was introduced, and preferred fuel, fodder, and timber species were planted; water harvesting practices and a complete halt to open grazing were introduced with the help of the *van panchayat* and the villagers
- From 1996-1999—area managed by the community and monitored by the GB Pant Institute of Himalayan Environment and Development as part of the People and Resource Dynamics Project (PARDYP)

Materials and Methods

The experimental area covered about 1/2 ha in the upper portion of the site where no active plantation had been done. It was divided into ten sectors. The plant/microbial populations and changes in soil characteristics in the sectors were studied from 1993 to 1998.

For phytosociological studies, 50x50 cm quadrats were laid within each plot during the first week of October (post-monsoon period) each year. This sampling coincided with the peak live biomass of ground vegetation, mainly grasses and herbs. Vegetation was clipped to ground level, and each species was separated and taxonomically classified into C_3 and C_4 species following Raghvendra *et al.* (1978), Naithani (1984, 1985), Chowdhery *et al.* (1984), Babu (1977), and Samant (1987).

Analytical features such as density, frequency, abundance, and importance value index (IVI) were determined following Misra (1968) and Saxena and Singh (1982). Tillers of the grasses were counted to measure densities and a digital vernier caliper was used to measure the diameter of each recorded species.

Three groups of soil microorganisms (fungi, bacteria, and actinomycetes) were enumerated in triplicate using the serial dilution technique (Johnson 1972). Mycological agar, nutrient agar, and actinomycetes isolation agar (from Hi Media, Bombay, India) were used to culture fungi, bacteria, and actinomycetes, respectively. Bacteria and actinomycetes were identified on the basis of their colour and shapes, and fungi were identified following the methods of Gilman (1987), Ellis (1971), Booth (1971), Barnett (1960), and Pitt (1979).

Soil samples were collected from study plots from 0-30 cm depth. Plant litter (the undecomposed and semi-decomposed top layer) was removed from the soil surface before each core was collected. Analyses of the soil parameters were done following the methods of Allen (1989).

Results and Discussion

Community Composition Changes

The importance value index (IVI) of the different species identified at the site were recorded each year from 1993 to 1998 (Table 94). The dominant species recorded at the site was *Imperata cylindrica*, a C_4 grass species. It had a maximum IVI value of 128 in the first study year (1993) which fell with each succeeding year to 108 in 1998. Twenty-eight species were recorded in 1993 and this increased to 52 in 1998. The number of C_4 species recorded increased from two in 1993 to eight in 1996/98; but the total IVI values of these species dropped from 150 in 1993 to 130 in 1998 (150, 142, 138, 133, 133, and 130).

Table 94: **Changes in the Importance Value Index (IVI) of Plant Species from 1993 to 1998**

Species Name	1993	1994	1995	1996	1997	1998
Chrysopogon serrulatus C_4	21.3	20.1	14.54	11.71	11.05	9.15
Imperata cylindrica C_4	128.5	122.1	121.76	112.74	110.24	108.23
Euphorbia prolifera	11.24	10.8	5.35	5.32	4.11	3.21
Indigofera dosua	38.76	43.8	45.47	44.64	44.74	44.98
Gnaphalium hypoleucum	4.2	2.1	1.48	1.44	1.19	1.08
Erianthus rufipilus	19.11	17.7	17.21	16.21	16.26	16.34
Adiantum lanulatum	1.0	2.2	2.53	2.79	3.84	3.46
Origanum vulgare	3.0	2.0	3.66	4.2	3.94	3.9
Cheilanthus albomarginata	1.27	1.3	2.18	2.73	3.94	3.89
Gloriosa superba	2.0	1.9	1.4	1.14	1.98	1.79
Oxalis corniculata	6.0	7.8	8.46	7.53	7.56	7.89
Potentilla fulgens	4.06	5.02	6.47	5.16	5.21	5.01
Crotalaria semialata	3.23	5.3	3.83	5.58	4.16	4.9
Micromeria biflora	8	8.6	8.26	8.49	9.94	8.56
Phyllanthus simplex	2	2	2.64	1.05	1.04	1.21
Calamintha umbrosa	3	2.08	2.26	2.57	2.96	2.89
Craniotome furcata	1	1	0	1.14	0	0
Cassia mimosoides	7.6	11.45	11.31	11.22	9.45	9.46

Table 94: **Changes in the Importance Value Index (IVI) of Plant Species from 1993 to 1998 (cont'd)**

Species Name	1993	1994	1995	1996	1997	1998
Flemingia sambuense	1	1.1	0	1.2	0	0
Pareitaria debilis	2	2.3	3.86	3.18	1.61	0.78
Desmodium triquetrum	10	11.3	14.07	10.74	8.14	8.67
Begonia picta	3.56	3.3	4.06	4.29	4.4	3.56
Drosera peltata	6.21	4.3	1.23	0.18	0.16	0.12
Artemisia parviflora	2.04	2.1	2.35	1.26	0.15	0.34
Erigeron Canadensis	4	4.7	3.66	3.78	2.94	2.99
Polygala abyssinica	1	1.5	0.85	0.24	1.89	1.34
Scrophularia calycina	3.63	1.01	1.13	1.8	1.08	1.34
Crotalaria sessilifera	1	2	1.38	2.19	1.9	1.07
Fimbristylis miliacea C_4	0	0	2.15	1.98	0.87	1.34
Barlaria cristata	0	0	1.38	1.89	1.64	1.34
Centranthera nepalensis	0	0	1.42	1.47	1.49	1.34
Erigeron bonariensis	0	0	1.53	0.66	0.94	0.9
Androsace rotundifolia	0	0	2.63	1.95	1.42	0.9
Arundinella nepalensis C_4	0	0	0	0.36	1.89	1.67
Bothriochloa pertusa C_4	0	0	0	0.9	1.9	1.78
Cyperus compressus C_4	0	0	0	2.4	2.42	2.23
Dicanthium annulatum C_4	0	0	0	1.86	2.94	2.34
Setaria glauca C_4	0	0	0	1.08	1.25	2.89
Fimbristylis ovata	0	0	0	0.48	1.19	1.9
Cynoglossum zeylanicum	0	0	0	1.2	0	0
Valeriana wallichi	0	0	0	1.44	1.96	2.09
Justicia pubigera	0	0	0	0.93	0	0
Polygonum nepalensis	0	0	0	0.84	1.38	1.01
Cyanotis vaga	0	0	0	1.05	1.06	0.56
Lindernia sessilis	0	0	0	0.9	1.84	0.34
Euphorbia hirta	0	0	0	0.21	0	0
Zornia gibbosa	0	0	0	1.65	2.94	1.98
Evolvulus alsinoides	0	0	0	1.86	3.36	2.32
Justicia simplex	0	0	0	0.42	0	0
Lindernia crustacea	0	0	0	1.68	2.74	0.89
Heteropogon contortus	0	0	0	0	3.36	3.98
Bidens pilosa	0	0	0	0	2.96	3.13
Conyza stricta	0	0	0	0	0	0.67
Crotalaria albida	0	0	0	0	0	0.12
Arthraxon nudus	0	0	0	0	0	0.15
Lespedaza gerardiana	0	0	0	0	0	0.78
Antirhinum orontium	0	0	0	0	0	0.56
Apluda mutica	0	0	0	0	0	0.23

C_4 indicates species with a C_4 pathway

One of the most important indicators of soil fertility is the microbial population (Table 95). The microbial population density increased continuously from 1993 to 1998 with the maximum increment recorded during 1993-94 (39% and 18% for fungi and bacteria respectively). The genera *Penicillium and Aspergillus* dominated the populations (Table 96).

Table 95: **Microbial Population, Colony Forming Units per Gram of Dry Soil**			
Year	Fungi (x 10^3)	Bacteria (x 10^5)	Actinomyceles (x 10^5)
1993	74	95	20
1994	103	112	39
1995	122	129	44
1996	139	154	51
1997	147	158	54
1998	152	161	55

Table 96: **Identified Fungal Species—Colony-Forming Units per Gram of Dry Soil**						
Species names	1993	1994	1995	1996	1997	1998
Absidia sp.	0.13	0.33	0	0	0	0
Alternaria alternata	0.51	0.55	0.61	0	0.25	0.63
Aspergillus niger	0.13	0.64	1.35	1.76	2.39	2.29
Aspergillus flavus	0	0.66	0.37	0.23	0.12	0
Aspergillus fumigatus	0.64	0.64	0.73	1.06	0.37	0.25
Aspergillus sp.	0	0	0	0.23	0.88	0.88
Botrytis sp.	0.38	0.93	0	0	0	0
Cladosporium sp.	0.25	0.66	0.87	0.95	0.62	0.5
Colletotricum sp.	0.25	0	0	0	0	0
Curvularia sp.	0	0.11	0	0	0	0.12
Drechslera sp.	0	0	0.24	0	0	0
Fusarium sp.	0	0	0	0	0.12	0.25
Gliocladium sp.	0	0.33	0	0	0	0
Helminthosporium sp.	0.38	0.44	0	0	0	0
Hormodendrum sp.	0	0.11	0	0	0	0
Mucor sp.	0.13	0.11	0.12	0.58	0.62	0.55
Penicillium expansum	2.19	1.21	2.69	2.84	2.27	2.29
P. chrysoginium	0	0.11	0.75	0.12	0	0
P. sp.	0	0.87	0.12	0.58	0.75	1.26
Paecilomyces sp.	0	0	0	0	0.5	0.76
Rhizopus sp	0	0	0.12	0.58	0.37	0.25
Trichoderma koningi	0.88	0.55	1.24	1.41	1.26	1.52
T. harzianum	0.64	0.33	0.36	1.06	0.5	0.13
Monila sp.	0	0.11	0	0	0	0
Verticillium sp.	0.25	0	0	0	0	0
*White sterile mycelia**	0.64	1.22	1.86	1.65	2.51	2.29
*Grey sterile mycelia**	0	0.37	0.75	0.83	0.37	0.88
*Black sterile mycelia**	0	0	0	0	0.75	0.38
* Specific identification was not possible because there was no sporulation						

Changes in Soil Nutrients

The soil chemical and physical conditions improved during the six-year study period (Table 97). There was a significant increase in soil moisture, organic carbon, total nitrogen, available phosphorus, and available potassium, and the pH improved from 5.9 in 1993 to 6.2 in 1994, remaining more or less constant thereafter.

Table 97: **Changes in Soil Properties from 1993 to 1998**						
Year	Moisture %	pH	Organic Carbon %	Total Nitrogen %	Available Phosphorus (kg/ha)	Available Potassium (kg/ha)
1993	12.3	5.9	1.02	0.012	7.2	134
1994	19.9	6.2	1.08	0.012	8.9	157
1995	20.1	6.3	1.12	0.022	9.2	189
1996	20.6	6.4	1.44	0.019	9.2	181
1997	21.2	6.4	1.44	0.021	11.1	190
1998	21.4	6.3	1.45	0.021	11.4	192

Discussion

The species composition within any ecosystem is strongly influenced by multiple factors including soil characteristics (Tilman 1990; Tilman and Wedin 1991), grazing (Rana and Rekhari 1994), climate (Teeri and Stowe 1976), and altitude (Tiezsen *et al.* 1979). This study provided significant information about changes in the characteristics of a particular ecosystem that had been under significant grazing pressure for a long time. The dominance of C_4 plant species and their changing status from 1993 to 1998, associated with changes in edaphic characteristics, agree with the findings of others who have compared plant community differences in relatively productive and unproductive sites. For example, a greater proportion of C_4 species is found in drier and low nitrogen soils (Black 1973; Tilman *et al.* 1996). Plants with a C_4 pathway possess a carbon concentrating mechanism in their bundle cells, and it is this unique feature that confers on them the adaptive advantages to survive in habitats with high temperatures, high irradiation, low soil nitrogen, and low moisture (Epstein 1997).

Imperata cylindrica and *Chrysopogon serrulatus* are the key species dominating the colonisation of such sites because of their higher water and nitrogen use efficiencies. *Imperata has a* vigorous root system and does not require precipitation to grow initially. Its sharp panicles cause problems for grazing by animals, this being a biological adaptation for survival.

Under heavy grazing pressure, even moderately resistant species may be eradicated if they are palatable. As a result, any species that is grazing intolerant is unable to colonise and, by the same token, species that are tolerant (or resistant) to grazing predominate. Grazing restricts the distribution and performance of potential competitors, allowing graze-tolerant or resistant species to spread. Moderate or heavy grazing pressure can significantly alter the relative abundance of graze-sensitive, graze-resistant, and graze-tolerant species within a community.

In this study, the emergence of new species from 1993 to 1998 after relief from grazing pressure corresponds to general findings that within a small enclosure, after relief from grazing, the species sensitive to grazing re-establish themselves in the secondary succession. Improvement in soil conditions also assists in the establishment of new species. Species may colonise an area if there are sufficient soil nutrients; but they may also become locally extinct because of dry conditions (Piper 1995).

The increase observed in the biodiversity during the study period is significant because it has been proven experimentally that more species-diverse plots use and retain nutrients more efficiently than do less species-diverse plots (Kareiva 1996), i.e., they become more productive. The increase in soil nutrients and moisture also plays a key role in increasing the microfloral population and activities. The abundance and physiological activity of the microflora in different habitats varies considerably, and these communities and their biochemical activities undergo appreciable fluctuations with time at any single site. Both generic composition and densities vary with soil physical and chemical characteristics (Gujaratis 1968; Misra 1966; Misra and Srivastava 1970; Rao 1986). Despite its small and variable mass, the microbial population is a very important constituent of a productive eco-system (Swift 1976). Its function is often compared to a sink and transformation strainer through which, sooner or later, all the carbon originating from the dead organic material passes (Paul *et al.* 1979). This microbial biomass responds sensitively to changes in the amounts and distribution of available carbon substances in an ecosystem.

Conclusion

Any ecosystem can be disturbed by changes in land use. A disturbance can turn an ecosystem into a battlefield between the forces of negentropy and entropy, or between development of an ecosystem organisation and its diminishment (Odum 1969). Every system is subject to an array of external inputs, for example water, radiant energy, wind, and gravity, all of which represent potential destabilising forces that may destroy or diminish the ecosystem organisation or damage its building bricks. For an ecosystem to maintain itself or grow, it must channel or fight these destabilising energetic forces in such a way that their full destructive potential is not achieved.

The dominance of C_4 species at the study area near Arah village suggests that degraded lands exposed to excessive grazing pressure still possess the potential to develop strategies to cope with or resist destabilising forces. The site is degraded in terms of soil condition, but the dominance of C_4 plants enables the ecosystem to sustain itself by drawing on a bank of energy and nutrients built up over a long period of time to solve immediate crises that may threaten still greater damage.

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Soil Fertility Status and Dynamics in the Jhikhu and Yarsha Khola Watersheds

Hans Schreier[1] and Pravakar B. Shah[2]
[1]Institute for Resources and Environment, University of British Columbia, Vancouver, Canada.
[2]International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Abstract

The soil fertility status in two different watersheds in the middle mountains region of Nepal was compared. The results showed that despite lower population pressure and reduced agricultural intensity in one watershed, the overall problems were the same: low pH, low carbon content, lack of available P, and low base cations. The lack of available phosphorus appears to be a key problem and, as shown in laboratory experiments, more than 50 per cent of the soils had very high levels of phosphorus sorption. The red soils had a particularly high absorption capacity and although irrigating red soils reduces the sorption by 20-25 per cent, the soils remained in the high absorption category. The fact that about 80 per cent of all soils in both watersheds have an undesirable pH (<5.0) contributes to the problem. The soils in the region are naturally acidic as a result of the dominance of acidic bedrock, but the extensive use of acid generating fertilisers and of pine litter in compost are contributing to the acid problem. A pine litter experiment showed that acidification from pine litter is a slow process and that different soils respond differently. It took 18 months of continuing litter addition (1kg/m^2 every 6 months) before a significant pH drop could be identified.

Introduction

For quite some time, concern has been expressed that the soil fertility in the middle mountains of Nepal is declining as a result of agricultural intensification, insufficient inputs into the cropping system, and excessive use of biomass from the forests. As pointed out by Schreier *et al.* (1994, 1995) the inherent geology gives rise to soils that are generally acidic and have low nutrient content. Furthermore, the lack of sufficient manure, inadequate access to fertilisers, and the increase in crop rotations, mean that soil fertility is not being sustained. The problems of low pH, low carbon content, deficiency of available P, and lack of base cations are widespread in the Jhikhu Khola watershed and questions have been raised as to whether these conditions are representative of the soil fertility status in the middle mountain region as a whole. At the same time, strategies are being developed to suggest how the soil fertility status can best be improved in the region (NARC 1997). Three experiments have been carried out to address these questions. A new soil fertility survey was started in the Yarsha Khola watershed, a laboratory study was carried out to determine phosphorus dynamics in red and non-red soils, and a selective land use study was started to determine if the extensive use of pine needles is acidifying agricultural soils.

The soil fertility survey in the Yarsha Khola watershed was carried out to determine the overall fertility status in a watershed that has a slightly higher elevation range, has less intensive crop rotations, and is located in a more remote setting than the Jhikhu Khola watershed. The survey was also intended to help determine whether the same factors (elevation, aspect, slope, and land use) influence soil fertility distribution as found in the Jhikhu Khola watershed (Schreier *et al.* 1995).

Phosphorus has been identified as one of the critical nutrients in the Jhikhu Khola watershed. As a result of the low soil pH and the lack of organic matter, P-availability appears to be the most limiting nutrient in agriculture, and a better understanding of P-dynamics is needed in order to be able to recommend steps to improve the P status in the soils. Red soils are of particular concern because many have pH values less than 4.3, and below this value Al and Fe solubility increase rapidly. With Fe and Al in the soluble form, Al-toxicity becomes a concern, and the problems are compounded by the fact that any available P will react with Fe and Al to form insoluble phosphates, thus depriving the plants of available P.

For many years the government of Nepal established chir pine plantations as the first phase of afforestation. The idea was to use native species that are easy to germinate in a nursery, that resist moisture deficiency, and that survive poor soil conditions once transplanted into degraded sites. The survival rate of these plantations was very good because the trees are not much favoured by the local people. They provide no fodder and the firewood is not very desirable because of the sparks generated in open fires. The pine will eventually provide timber, and it was anticipated that once the plantations were established secondary forest cover would take over. Unfortunately, the demand for fodder is so high that without restrictions much of the palatable understorey is used. The majority of these pine plantations are now 20-25 years old, and because of the removal of the understorey cover they provide only limited protection against soil erosion. As shown by Shrestha and Brown (1995) and Schreier *et al.* (1995, 1999), the forests in the Jhikhu Khola watershed are now dominated by chir pine as a result of the extensive forest rehabilitation programme in the 1980s. Because of the scarcity of organic matter in agriculture, it has long been the practice to collect forest litter during the dry season for animal bedding and subsequently incorporate it into the agricultural system. Since the forests have become progressively dominated by pine, the proportion of pine litter in the collection of forest material has increased. Although we have long been concerned about the effect of pine litter in acidifying soils, no scientific data has been available to show whether this is a legitimate concern under the Nepali agricultural conditions.

As a result of the dominance of quartzite, sandstones, and siltstones in the watershed, and the dominant use of acid producing fertilisers (ammonium sulfate and urea), the soils in the Jhikhu Khola watershed are now in a pH range that is well below the levels considered optimal for agricultural production. The question of whether the addition of pine litter is contributing further to the acidification process of the soil under these management practices in Nepal has not yet been addressed in any depth. As a result, a long-term experiment was set up to document the potential processes.

Methods

Soil Fertility Survey

A new soil fertility survey was conducted in the 5000 ha Yarsha Khola watershed. The basin was divided into 3 elevation classes, 2 aspect classes, 3 different geological units, and 4 land use classes. Based on this 3x2x3x4 matrix, a total of 72 unique soil/land use polygons were identified and an attempt was made to sample up to 10 sites for each combination of factors. Some 34 combinations of classes were actually found to be present in the watershed and 340 soil samples (150 from agricultural sites and 190 from forest and rangeland sites) were collected for a comprehensive soil fertility analysis. At the time of sampling, 150 farm households and representatives from 20 forest user groups were interviewed (short survey) and pertinent data were collected on crop production, input variables, and forest and fodder use. A more detailed PRA survey was undertaken with 75 individual households and this data will be used to make detailed nutrient budgets and for a socioeconomic analysis. The soil fertility conditions were determined in the laboratory using the standard soil analysis methods described by Page (1982). A comparison was then made with the extensive data set available from the Jhikhu Khola watershed.

Soil Phosphorus Experiments

Laboratory experiments were conducted to determine the key factors that are responsible for the low availability of P in the soils. They included a P-sorption experiment on red and non-red soils originating from irrigated and non-irrigated land. Fifty-nine samples were used in this subset; they were saturated with increasing P concentrations and Bray-P extractions were then carried out to determine the sorption isotherm. The results of the sorption capacity of the soils were then applied to the Bela sub-watershed (Jhikhu Khola Watershed) to determine how much of the watershed area would benefit most from the use of additional phosphorus fertiliser. Soils with low P-sorption capacity will make more of the applied phosphorus available to crops than will soils with high P-sorption capacity (details of the methods in Schreier *et al.* 1999).

Pine Litter Experiments

The question of whether pine litter addition is speeding up the acidification process was investigated in a long-term plot experiment on red and non-red soils. A series of 12 plots (50x50 cm in size) were replicated for each of the two soil types—red soils originating from phyllitic parent materials and brown soils from quartzitic materials. Soil samples were collected before pine litter addition. After this 1 kg/m^2 of dry pine litter was incorporated into the soil in each plot, and the same amount added again at intervals of six months to selected plots as shown in Table 98. The soils of all 12 plot segments were analysed before the experiment started and six months after each addition of pine litter. The soils underneath the added pine litter were sampled in a destructive manner and analysed for pH, exchangeable cations, carbon, and available phosphorus (Bray-1) using standard procedures as described by Page *et al.* (1982).

Table 98: **Plot Design for Pine Litter – Acidification Experiment**

1	2	3	4	5	6
7	8	9	10	11	12

Addition of pine litter every 6 months @ 1 kg/m^2						
Plot No.	Time	Time	Time	Time	Time	Time
1 + 7	1kg, Apr-96					
2 + 8	1kg, Apr-96	1kg, Oct-96				
3 + 9	1kg, Apr-96	1kg, Oct-96	1kg, Apr-97			
4 + 10	1kg, Apr-96	1kg, Oct-96	1kg, Apr-97	1kg, Oct-97		
5 + 11	1kg, Apr-96	1kg, Oct-96	1kg, Apr-97	1kg, Oct-97	1kg, Apr-98	
6 + 12	1kg, Apr-96	1kg, Oct-96	1kg, Apr-97	1kg, Oct-97	1kg, Apr-98	1kg, Oct-98

Results

Comparison of Soil Fertility Status in the Yarsha and Jhikhu Khola Watersheds

The problems of low pH, low carbon content, and deficiency of available P are widespread in the Jhikhu Khola watershed (JKW) and have been well documented by Schreier *et al.* (1994), Shah and Schreier (1995), and Brown and Schreier (this volume). With the partial completion of the Yarsha Khola watershed (YKW) soil fertility survey, it is now possible to compare the two watersheds.

The maximum, minimum, and mean values for various soil fertility factors in the two watersheds are shown in Table 99. The results show that:

- the percentage soil carbon is significantly higher in the YKW,
- the available phosphorus (Bray-1) is significantly lower in the YKW,
- the pH values are very similar in both areas.

To express the adequacy of the soil fertility better we set two tolerance thresholds, a conservative and a more lenient threshold. A one per cent soil carbon level is considered

Table 99: **Comparison of Soil Fertility Values in the Jhikhu and Yarsha Khola Watersheds**

	% C		pH		Avail. P mg/kg	
	JKW	YKW	JKW	YKW	JKW	YKW
mean	1.0	1.4	4.65	4.75	16.5	4.8
maximum	0.1	0.1	3.97	3.59	1.4	0.1
minimum	3.7	6.5	6.70	7.42	127.1	52.4
n	200	340	200	340	200	340

adequate in these Nepalese environments and a 1.5 per cent level is desirable. Similarly, a pH level of 5 is adequate and a level of 5.5 is desirable, and an available P level of 12 mg/kg is adequate and 15 mg/kg desirable. Figure 108 shows the percentage of the soil samples from the two areas with values above these threshold values.

Only about one third of all samples in the JKW had adequate percentage C levels compared with two thirds of the YKW samples (Figure 108a). This can be explained at least partially by the elevation and climate factors. Soil carbon tends to increase with elevation since temperatures become cooler and decomposition is slower, an effect noted previously by Wymann (1989) within the Jhikhu Khola watershed. Other factors that influence the carbon pool are:

- higher population density resulting in more intensive use of forests and less availability of organic litter;
- more use of fertilisers because of the introduction of cash crops; and

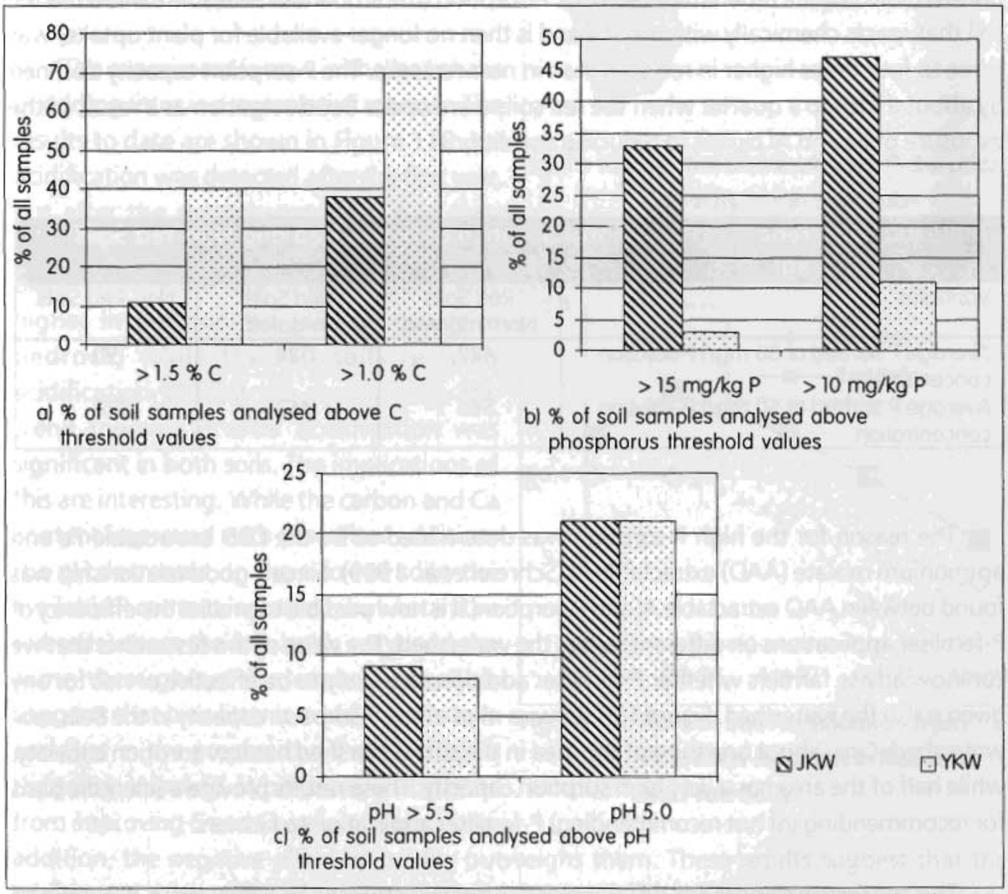

Figure 108a-c: **Comparison of Soil Fertility in the Jhikhu and Yarsha Khola Watersheds Based on Two Different Threshold Values, Adequate and Desirable, for C, Available P, and pH (JKW n = 200, YKW n = 340)**

- significantly higher crop rotations (average 2.7 crop rotations per year in the JKW compared with1.9 crop rotations per year in the YKW).

Only 10 per cent of the samples from the YKW had adequate P levels (Figure 108b), compared with 45 per cent of those from the JKW. One of the reasons for this difference is that phosphate fertilisers are often used in the JKW but only rarely in the YKW.

Soil acidity is of great concern. Only 20 per cent of all samples from both areas had adequate pH values and less than 10 per cent pH values in the desirable range (Figure 108c). There was no difference in the soil acidity between the two sample sets. The low values have serious implications for organic matter decomposition, P availability, Al toxicity and micro-nutrient availability.

Results from P Sorption Experiments

The laboratory experiments showed that the phosphorus sorption capacity of red and non-red soils is quite different (Table 100). P-sorption (the amount of available P added to the soil that reacts chemically with the soil and is then no longer available for plant uptake) was three to four times higher in red soils than in non-red soils. The P-sorption capacity declined by about a fifth to a quarter when the red soils were under flood irrigation as a result of the exposure of Fe and Al oxides to reducing conditions.

Table 100: **Differences in Phosphorus Sorption between Red and Non-red Soils (mg/kg)**

Variables	Red Soils Non-irrigated	Red Soils Irrigated	Non-Red Soils
Average P sorbed at 30 mg/l P-solution concentration	422	320	190
Average P sorbed at 50 mg/l P-solution concentration	565	462	261

The reason for the high P-sorption was determined to be the CBD extractable Fe and ammonium oxalate (AAO) extractable Al (Schreier *et al.* 1999). Since a good relationship was found between AAO extractable Al and P-sorption, it is now possible to predict the efficiency of P-fertiliser applications on different soils in the watershed. The value of this research is that we can now advise farmers whether P-fertiliser additions are likely to be effective or not for any given soil in the watershed. Figure 109 shows a map of the P-sorption capacity in the Bela sub-watershed. Only about one third of the area in the sub-watershed has low sorption capacity, while half of the area has a very high sorption capacity. These results provide a scientific basis for recommending (or not recommending) P-fertiliser application to farmers.

The nutrient balances for different agricultural systems in the JKW were determined during additional research carried out by Brown (1997), Brown *et al.* (1999), and Brown and

Schreier (this volume). The results confirm that not only is phosphorus deficient in most soils but that there is an annual deficit in inputs. Rainfed maize dominated crop rotations were found to have the greatest P deficits, while the irrigated rice systems were at a much lower risk of long term losses of nutrients. The results indicate that current management practices are mining the soil nutrient pool and if continued may have a long-term negative impact on productivity—unless greater efforts are made to increase manure and fertiliser inputs and to promote mycorrhizal inoculation.

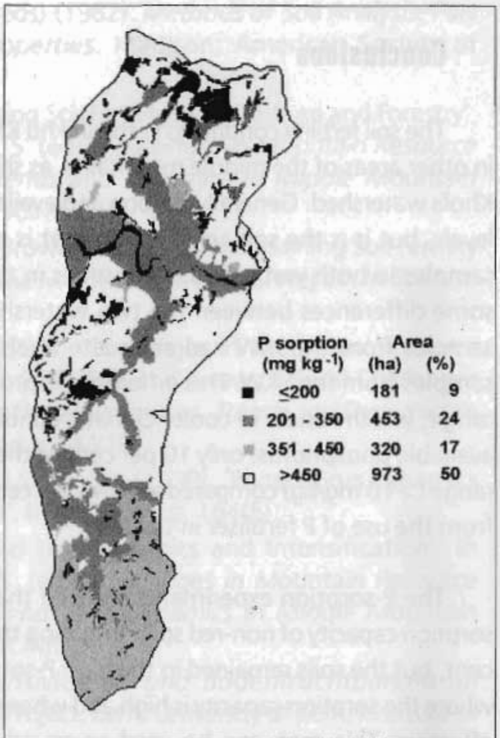

Figure 109: **Spatial Distribution of P-Sorption Capacity in the Bela sub-watershed**

Results of the Pine Litter Acidification Experiment

The experiment is now in the last phase of adding litter in a cumulative manner. The results to date are shown in Figure 110. No acidification was detected after the first year, but after the second year there was clear evidence that soil acidification was taking place. Initially the rate of acidification was higher in the non-red soils on quartzite bedrock, while the red soils resisted acidification. During the second year, the trend towards greater acidification was significant in both soils. The implications of this are interesting. While the carbon and Ca content improved with pine litter addition, the pH decreased. In the non-red soils, the available P content increased, but not in the red soils where the low levels remained the same throughout the experiment. This suggests that pine litter is acidifying the soils and that in the process the P availability in red soils is impaired. While there are benefits from improving C and Ca values by pine litter addition, the negative effect on acidity outweighs them. These results suggest that the addition of other types of litter is needed for there to be a positive impact on nutrient management.

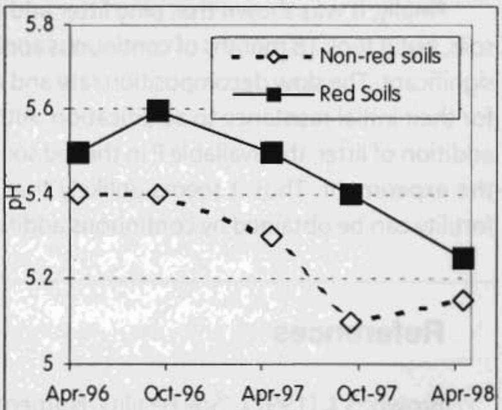

Figure 110: **Rate of Soil Acidification from Pine Litter Addition in Red and Non-red Soils**

Conclusions

The soil fertility conditions in the Jhikhu Khola watershed are representative of conditions in other areas of the middle mountains, as shown in the comparative study with the Yarsha Khola watershed. Generally, carbon and available phosphorus levels are well below desirable levels, but it is the soil acidification that is of greatest concern. About 80 per cent of all samples in both watersheds had values in the inadequate pH range of <5.0. There were some differences between the two watersheds in terms of soil carbon: one third of the samples from the JKW had adequate levels (>1% C), compared with two thirds of the samples from the YKW. This difference is probably explained by the difference in elevation range, which results in cooler climatic conditions. The reverse situation was observed for available phosphorus: only 10 per cent of the samples from the YKW were in the adequate range (>10 mg/kg) compared with 45 per cent of those from the JKW. This difference results from the use of P fertiliser in the JKW.

The P-sorption experiments showed that red soils had almost twice the phosphorus sorption capacity of non-red soils. Irrigating the red soil reduced the sorption by about 25 per cent, but the soils remained in the high P-sorption category. A map was produced to show where the sorption capacity is high and where the application of P-fertiliser might not be very effective. This map can be used as an advisory tool for farmers in making P-fertiliser application recommendations. More than 50 per cent of the Bela sub-watershed was shown to have soil conditions that are unlikely to respond significantly to P fertiliser applications.

Finally, it was shown that pine litter additions to red and brown soils are acidifying the soils, but it took 18 months of continuous application of litter before the acidification became significant. The slow decomposition rate and Al buffering in the red soils are the likely reason for their initial resistance to acidification. Although the soil carbon can be improved by the addition of litter, the available P in the red soils did not increase significantly over the time of the experiment. Thus it seems unlikely that significant improvements in agricultural soil fertility can be obtained by continuous addition of pine litter.

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Nutrient Budgets: A Sustainability Index

Sandra Brown and Hans Schreier
Institute for Resources and Environment, University of British Columbia, Vancouver, Canada

Abstract

The sustainability of agricultural production systems in the middle mountains of Nepal is dependent on soil and water resources, management, and market factors. However, maintaining the soil nutrient pool is the key to long-term productivity. Nutrient budgeting was used to evaluate inputs, management, and productivity, and to quantify the impact on soil fertility. Data from soil, water, and sediment analysis, and from socioeconomic farm surveys, provided inputs to the model. Soil N, P_2O_5, and Ca budgets were calculated. The results for the main cropping systems indicated substantial deficits for N and P_2O_5 under a rainfed maize-dominated rotation. Nitrogen deficits under this system were comparable to crop requirements. By comparison, nitrogen deficiencies appeared to be the only concern under triple cropping systems in a rotation dominated by irrigated rice. Nutrient budgets indicated that the soil nutrient pool is being depleted under both extensive rainfed and intensive irrigated production systems, and are an indicator of soil degradation. Prevention and rehabilitation techniques such as liming, improved composting, and integrated nutrient management must be incorporated into farm production systems if productivity is to be maintained.

Introduction

The current soil fertility status and how it is changing are strongly influenced by nutrient management. As agriculture intensifies and expands onto marginal lands, concern has been expressed that the nutrient pools in the soil cannot be sustained. There are three areas of major concern:

- double and triple crop rotations are now common where water is available;
- high yielding varieties and vegetable crops are more nutrient demanding; and
- organic matter inputs traditionally applied to upland fields are being applied to cash crops.

Chemical fertilisers and forest litter are used in an attempt to maintain production, but farmers are reporting that increased fertiliser inputs are required to maintain yields. Nutrient budgeting provides one mechanism for evaluating inputs, management, and productivity, and their impact on soil fertility.

The following nutrient budget model was developed for and then applied to the Jhikhu Khola watershed in the middle mountains of Nepal to demonstrate its application. In the model, nutrient inputs to and losses from the soil nutrient pool are estimated. The data requirements and model assumptions are outlined below. Soil samples from 130 agricultural fields were analysed. Data were collected for each field on the crops grown, inputs applied, and yields. Erosion plot, sediment accumulation, and water quality data were collected and incorporated into the model. In addition, a special study on phosphorus fixation was conducted to determine P constraints—particularly in red soils, which are known to have low P supplies (Schreier *et al.* 1999). Nutrient budgets are presented for the dominant cropping systems in the watershed and the implications for sustainability are discussed. Specific emphasis was given to rice dominated (irrigated) and maize dominated (rainfed) cropping systems.

Modelling Method

The impact of management practices on agricultural soil fertility was quantified by modelling nutrient inputs, redistribution, and losses. The approach and assumptions used to model soil N are shown diagrammatically in Figure 111. A similar framework was used to model P_2O_5 and Ca. Nutrient flows were integrated over a soil depth of 15 cm. Nutrient inputs were associated with compost, fertiliser, sediment, water, and biota; redistribution processes included erosion-sedimentation, mineralisation-immobilisation, and adsorption-desorption; and losses included leaching, denitrification, volatilisation, chemical fixation, erosion, and plant uptake. Compost additions were subjected to mineralisation and retention, and provided nutrients to subsequent crops through organic residues.

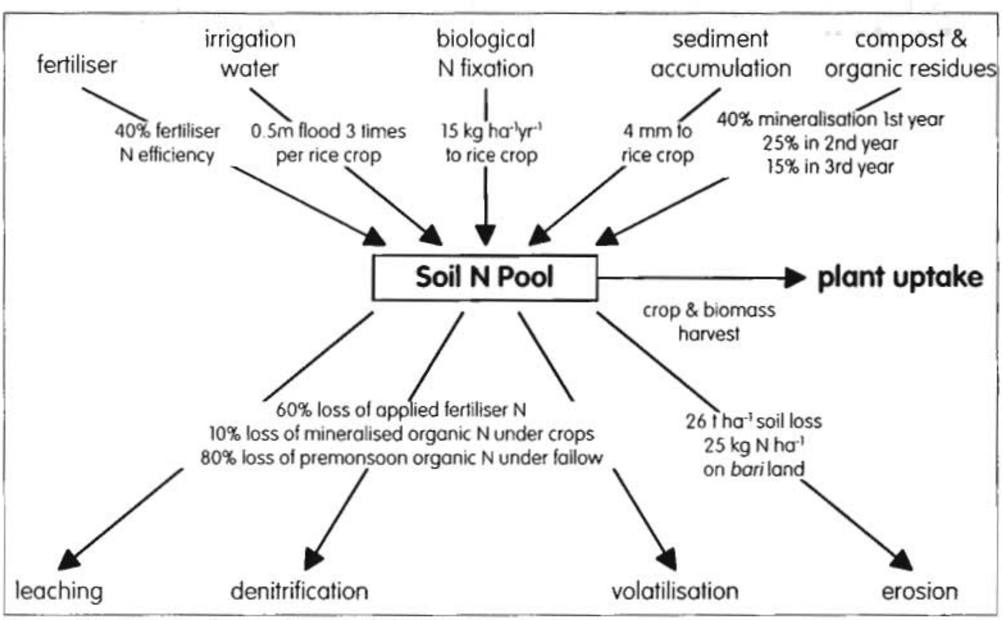

Figure 111: **Approach Used to Model Soil N Dynamics**

Data Requirements

Information from socioeconomic surveys and biophysical analyses of soil, water, and sediment samples is required in order to use such a model. Input to the nutrient budget requires data on soil fertility, biomass productivity, farm management, and soil loss from erosion plots. In addition, data from the literature are needed for verification and to fill information gaps.

Initial Soil Nutrient Pool

The initial pool of soil nutrients was calculated from the current soil fertility status for each land use category. The potentially available soil nutrient pools for N, P_2O_5, and Ca in irrigated and rainfed land were calculated from the measured soil nutrient concentration, assuming a soil bulk density of 1400 kg/m³ and a 15 cm rooting depth. An example of the calculations (for P_2O_5 in rainfed land) is shown below. The results are shown in Table 101.

$$\frac{47 \text{ mg } P_2O_5}{\text{kg soil}} \times \frac{\text{kg}}{10^6 \text{ mg}} \times \frac{1400 \text{ kg soil}}{m^3} \times \frac{100 \times 100 \ m^2}{\text{ha}} \times 0.15 \text{ m} = \frac{99 \text{ kg } P_2O_5}{\text{ha 15 cm soil depth}}.$$

For each land use category, nutrient additions and/or losses will apply.

Table 101: **Initial Soil Nutrient Pool (mean values)**

Land Use	Soil Nutrient Concentration (mg/kg)			Soil Nutrient Pool (kg ha⁻¹, 15 cm soil depth)		
	N	P_2O_5	Ca	N	P_2O_5	Ca
Irrigated	854	49	2120	1793	103	4452
Rainfed	941	47	1443	1976	99	3030

Compost and Fertiliser Use

Inputs from compost and chemical fertiliser sources to cultivated land were based on the responses from the farmers surveyed. The nutrient inputs to rice, maize, and wheat crops from organic matter and chemical fertiliser sources are summarised in Table 102. The inputs from compost were calculated for traditional compost practices assuming 0.6% N, 0.06% P_2O_5, and 0.6% K_2O (Subedi *et al.* 1995), and a 25% moisture content.

The greatest amount of organic matter was applied to maize grown on rainfed lands during the monsoon. Farmers applied an average of 12 tonnes per ha, and in some cases up

Table 102: **Reported Nutrient Inputs from Organic and Chemical Fertiliser Sources (n=130)**

System	N	Med. Organic Matter Inputs (kg ha⁻¹)				Med. Che. Ferti. Inp. (kg ha⁻¹)		
		Amount	N	P_2O_5	Ca	Amount	N	P_2O_5
Premonsoon								
Early maize (irrigated)	12	0	0	0	0	177	35	35
Monsoon								
Rice (irrigated)	49	2,457	11	1	15	197	57	39
Maize (rainfed)	65	11,795	53	5	71	172	35	27

to 50 tonnes per ha, of organic fertiliser to rainfed lands during the monsoon season. During the winter, only 18 per cent of farmers applied organic matter to rainfed fields. Organic matter inputs to irrigated fields were lower, roughly four tonnes per ha in total, and were distributed over the premonsoon and monsoon periods. The calculated average inputs show the relatively small contributions made by organic matter to N and P_2O_5 with the exception of maize grown during the monsoon. In contrast, organic matter was the main source of Ca on rainfed fields.

The dominant chemical fertilisers used were urea (46-0-0), complex C (20-20-0), and ammonium sulphate (21-0-0), and mainly supplied inorganic N. Chemical fertiliser inputs were applied throughout the year, with monsoon rice receiving the largest N and P_2O_5 inputs. Nutrient inputs from chemical fertiliser were significantly greater than those from organic matter with the exception of maize grown during the monsoon, which received 52 per cent of N inputs and 20 per cent of P_2O_5 inputs from organic sources. At the other extreme, winter wheat typically received all N and P_2O_5 inputs from inorganic sources.

Erosion

The annual nutrient losses through erosion were estimated from the erosion rates determined in plot studies and the nutrient content of eroded sediments. The results are shown in Table 103. The erosion rates averaged 26±5 t per ha on rainfed sites (Carver 1997). Average erosion rates were used to estimate nutrient losses under farmers' practice and lower estimates of erosion rates were used to simulate best management practices. For rainfed lands, the nutrient content of sediments eroded from the plots were used to estimate annual losses. Eroded sediments commonly contain a higher nutrient content than the topsoil from which they are derived as a result of the selective erosion of organic matter and surface soil high in nutrients. Nutrient losses through erosion from rainfed fields resulted in an average annual loss of 25 kg N per ha and 23 kg Ca per ha. Available P losses were small, but the organic P losses may be high, particularly if a high intensity rainfall event occurs before compost and manure are incorporated into the soil.

Table 103: **Erosion and Associated Annual Nutrient Losses from Rainfed Lands**

	Nutrient Content ($mg\ kg^{-1}$)		Erosion		Depth Integrated Losses ($kg\ ha^{-1}$ per soil loss depth)		
	Eroded Sediment	Residual Soil	Rate ($t\ ha^{-1}$)	Soil loss (mm)	Eroded Sediment	Residual soil	Losses
Rainfed fields			26 + 5	2			
N	1882	941			49	24	25
Avail. P_2O_5	64	47			1.7	1.2	0.5
Ca	1980	1443			51	28	23
Total bases	2777	1937			72	50	43

Water Management and Sedimentation

The annual nutrient inputs to lowland irrigated fields from sediments were calculated based on the amount and nutrient content of accumulated sediment. Sediment accumulation was measured in 20 irrigated fields and the nutrient content of newly accumulated and residual soils determined. Given a median annual sediment accumulation of 4 mm, and assuming a soil bulk density of 1400 kg per cu m, an additional 11 kg N per ha and 28 kg Ca per ha were potentially available for plant uptake. Nutrients may also be gained by irrigated fields through irrigation water. Spring and stream water samples taken during the dry season of 1990 (Schreier *et al.* 1994) indicate that the water is alkaline and contains moderate quantities of Ca, Mg, NO_3, and PO_4. Assuming a 0.5m depth of water applied three times per rice crop, the irrigation water may contribute an additional 6 kg N per ha and 300 kg Ca per ha.

Phosphate Fixation

The high phosphate fixation capacity of soils in the study region has important implications for P management (Schreier *et al.* 1999). The P sorption potential for these soils is given in Table 104. The P sorption capacity averaged 6,700 kg P_2O_5 per ha for red soils and 1,500 kg P_2O_5 per ha for non-red soils, values comparable to tropical soils high in kaolinite. Given the high potential for fixation, P released to the soil solution will be governed by the chemical equilibria between soluble and insoluble mineral forms of P, the slow release of inorganic P by mycorrhizal fungi and other micro-organisms, and by mineralisation and immobilisation of organic P. Fertiliser P application, particularly on red soils, will be inefficient and crops will probably recover only 20 to 40 per cent of the P applied in organic inputs annually (Sharpley and Halvorson 1994).

Table 104: **Phosphate Sorption Potential**

Soil	Description		P Sorption Capacity	
			g P (kg soil)-1	kg P_2O_5 ha-1
Red Soils	Forest	n = 10	1.7	8200
	Cultivated	n = 20	1.2	5900
Non-red Soils	Cultivated Rangeland	n = 26	0.3	1500

Yield and Crop Nutrient Uptake

The nutrient uptake by the main staple crops grown in the region was calculated from reported yield data and average values of N, P_2O_5, and Ca uptake derived from literature sources. Reported yields for rice, maize, and wheat were compared to regional values and locally measured yields to assess the validity and variability of yields reported by farmers. Nutrient removal by rice, maize, and wheat is summarised in Table 105. The per cent nutrient composition by weight refers to the entire above ground portion of the crop. Nutrient uptake by the total biomass was utilised as crop residues are harvested and used for animal feed. Reported yield values were used to estimate total dry matter based on the ratio of grain to total biomass. For rice, maize, and wheat, grain comprises roughly 45 per cent of total dry matter (Grist 1986). The total estimated dry matter on a kg per ha basis was then multiplied by the per cent nutrient composition to calculate N, P_2O_5, and Ca uptake.

Table 105: **Nutrient Removal by the Dominant Staple Crops (median values)**								
System	Rep. Yield (kg/ha)	n	Average Composition			Nutrient Uptake (kg/ha)		
			% N	% P_2O_5	% Ca	N	P_2O_5	Ca
Premonsoon								
early maize (irrigated)	1054-6389	12	1.4	0.6	0.3	67	29	14
Monsoon								
rice (irrigated)	959-7669	49	1.0	0.4	0.1	75	30	8
maize (rainfed)	688-8256	66	1.4	0.6	0.3	128	55	27
Winter								
wheat	334-5351	53	1.2	0.5	0.1	36	15	3
wheat (irrigated)	669-5351	31	1.2	0.5	0.1	45	19	4
wheat (rainfed)	334-2675	22	1.2	0.5	0.1	36	15	3

Nutrient uptake was greatest for maize grown during the monsoon with a median value of 128 kg N, 55 kg P_2O_5, and 27 kg Ca removed per ha. Monsoon rice removed roughly 75 kg N, 30 kg P_2O_5, and 8 kg Ca per ha, while premonsoon maize and rice removed intermediate levels of N, P_2O_5, and Ca. Wheat, the main crop grown during the winter, removed the least nutrients with a median uptake for irrigated and rainfed sites of 36 kg N and 15 kg P_2O_5 per ha. These values cannot be taken as precise since the nutrient composition of crops varies substantially with differences in soil nutrient availability, plant genotype, and local environmental conditions. However, these estimates of nutrient uptake for specific fields provide an indication of the level of nutrient inputs required to maintain the soil nutrient pool.

Model Assumptions

Organic matter mineralisation was assumed to be 40 per cent in the first year, 25 per cent in the second year, and 15 per cent in the third year (Kirchman 1994). Inputs from traditional compost are subjected to storage and handling losses prior to incorporation and further N losses under crops are likely be small. N losses under fallow, however, may be substantial and were assumed to be 70 per cent. Crop recovery of applied fertiliser N was taken to be 40 per cent, that is 60 per cent losses were assumed due to leaching, volatilisation, and denitrification (Stevenson 1986). Phosphate fixation by Fe and Al oxides was assumed to be 73 per cent of applied fertiliser P and 10 per cent of mineralised organic P on red soils and 53 per cent of applied fertiliser P on non-red soils, with a subsequent slow release of 15 per cent per annum by chemical and microbial processes (Sharpley and Halvorson 1994). Ca losses by leaching were taken to be 40 per cent for all sources, and 30 per cent Ca fixation was assumed under rice production (Cook 1981). The Ca required to neutralise the acidifying effects of chemical fertilisers (dominantly urea) was taken to be 1 kg CaO per kg N applied.

Results of Nutrient Budget Calculations for the Dominant Cropping Systems

The nutrient budgets were calculated for a rainfed maize-wheat rotation and an irrigated early maize-rice-wheat rotation. The results are shown in Figures 112a-f. The calculated N, P_2O_5, and Ca inputs and withdrawals are shown in the upper and lower portions of the pie charts, respectively. The 'inputs from compost' indicate the total nutrients contained in the

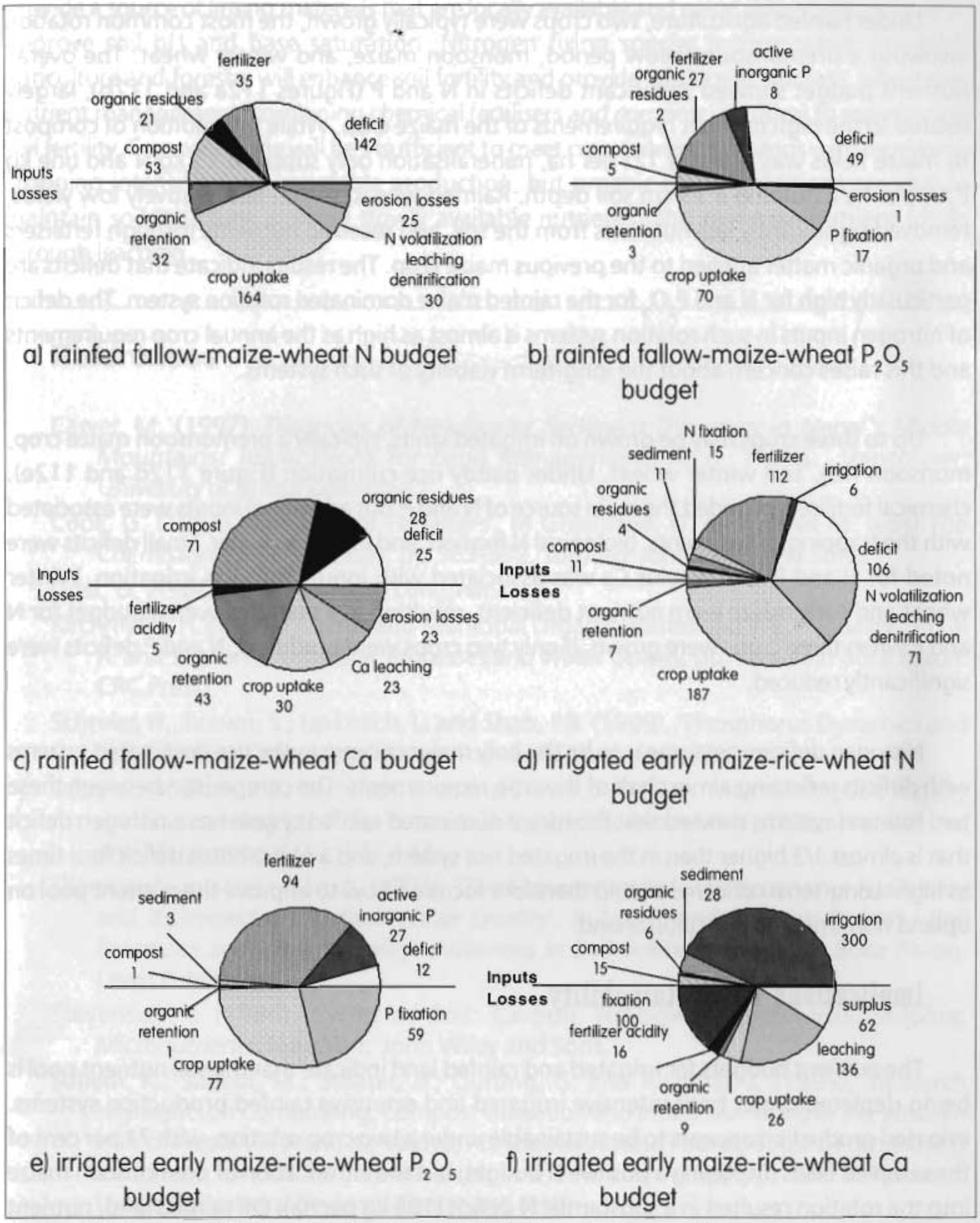

Figure 112: **Annual Nutrient Budgets for Rainfed and Irrigated Cropping Systems (numbers refer to kg per ha per 15 cm soil depth)**

organic matter applied to the crop, the 'organic residues' show the nutrient supply from prior compost applications, and the 'organic retention' refers to compost which is not decomposed during the growing season. 'Phosphorus fixation' indicates the absorption of P by Al and Fe oxides, and 'active inorganic P' refers to the slow release of inorganic P from prior inputs. Median values of compost, fertiliser, and crop uptake for households growing each crop were used.

Under rainfed agriculture, two crops were typically grown, the most common rotation involving a premonsoon fallow period, monsoon maize, and winter wheat. The overall nutrient budget showed significant deficits in N and P (Figures 112a and 112b), largely related to the high nutrient requirements of the maize crop. While the addition of compost to maize fields was typically 12t per ha, mineralisation only supplied 13 kg N and one kg P_2O_5 per ha assuming a 15 cm soil depth. Rainfed wheat, which has relatively low yields, removed significantly less nutrients from the soil, and received nutrients through fertilisers and organic matter applied to the previous maize crop. The results indicate that deficits are particularly high for N and P_2O_5 for the rainfed maize dominated rotation system. The deficit of nitrogen inputs in such rotation systems is almost as high as the annual crop requirements and this raises concern about the long-term viability of such systems.

Up to three crops may be grown on irrigated lands, typically a premonsoon maize crop, monsoon rice, and winter wheat. Under paddy rice cultivation (Figure 112d and 112e), chemical fertilisers provided the main source of N and P, but additional inputs were associated with the trapping of sediments, biological N fixation, and irrigation water. Small deficits were noted for N and P, and surplus Ca was associated with inputs through irrigation. Winter wheat and early maize were nutrient deficient, resulting in a negative overall budget for N and P when three crops were grown. If only two crops were produced, N and P deficits were significantly reduced.

Nitrogen deficiencies appear to be the only major concern in the rice dominated systems with deficits reflecting almost half of the crop requirements. The comparison between these two rotation systems showed that the maize dominated rainfed system has a nitrogen deficit that is almost 1/3 higher than in the irrigated rice system, and a phosphorus deficit four times as high. Long-term concerns should therefore focus on how to improve the nutrient pool on upland non-irrigated agricultural land.

Implications for Sustainability

The nutrient budgets for irrigated and rainfed land indicate that the soil nutrient pool is being depleted under both intensive irrigated and extensive rainfed production systems. Irrigated production appears to be sustainable under a two crop rotation, with 71 per cent of the sampled fields displaying a positive N budget, but the introduction of premonsoon maize into the rotation resulted in a substantial N deficit (106 kg per ha). On rainfed land, nutrient inputs were insufficient to meet crop requirements and the negative nutrient budgets are an indicator of soil degradation.

Prevention of further soil fertility degradation and rehabilitation of already degraded lands are challenges that must be addressed if productivity is to be maintained in the middle mountains of Nepal. Improved composting is one practical option for improving nutrient budgets under rainfed cultivation. Acidification is a concern because of the inherent acid bedrock, and the increasing use of chemical fertilisers. Calcium and magnesium based rocks provide a source of liming materials that are locally available and could potentially be used to improve soil pH and base saturation. Nitrogen fixing species incorporated into both agriculture and forestry will enhance soil fertility and provide additional biomass. Integrated nutrient management, combining chemical fertilisers and compost, is critical to maintaining soil fertility. Compost alone will be insufficient to meet crop nutrient demands with increasing cropping intensities and vegetable production, but organic matter additions are vital to maintain soil structure, provide slowly available nutrients, and minimise nutrient losses through leaching.

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Socioeconomic and Biophysical Interactions: Examples Relating to Soil Fertility

Sandra Brown
Institute for Resources and Environment, University of British Columbia, Vancouver, Canada

Abstract

The constraints and opportunities faced by farmers are influenced by social, economic, cultural, and biophysical factors. Socioeconomic indicators such as population growth, land tenure, and ethnicity play an important role in the management of resources and resource degradation. In the middle mountains of Nepal, population growth has led to double and triple annual crop rotations and increased pressure on forest resources. The results of the study described here showed the following interactions. The use of compost and chemical fertiliser varied with farm size and economic constraints, holders of medium-sized farms applied the greatest inputs and their farms exhibited the best nutrient budgets. Agrochemical use and crop production were affected negatively by uncertain land tenure arrangements, share-cropped fields were less intensively managed. Reductions in the availability of animal fodder and in access to grazing areas have resulted in an increase in stall feeding during the monsoon. The intense pressure on forest resources is reflected in the soil fertility conditions, the poorest soil fertility conditions in the region were found on forest and rangelands. Ethnic affiliation influences access to resources and is reflected in nutrient inputs. High caste households apply the most chemical fertiliser; whereas low caste groups concentrate their manure inputs on irrigated fields. The socioeconomic factors influencing nutrient dynamics are interrelated, but within the study area population growth and access to land were the two key factors.

Introduction

Local knowledge and experience play an integral role in decision making within traditional communities; however, rapid population growth, increasing pressure on the resource base, and the increased availability of western technology have accelerated change. Communities near major markets such as Kathmandu are no longer isolated but are changing as they become more integrated into the cash economy. Population growth, land tenure, culture, and poverty are the underlying socioeconomic factors influencing farming system dynamics in the middle mountains. The current status of the farming system and recent changes have had an effect on land use and nutrient management and thus on natural resources. The implications for resource dynamics are both direct and indirect, and provide further insight into why resource degradation is occurring.

The following examples are drawn from the Bela sub-catchment in the Jhikhu Khola watershed, Nepal. Surveys of 85 households were used to compile data on socioeconomic indicators and farm management (Brown in this volume). At each location field data were collected on the crops grown, and additional data were compiled on nutrient inputs and yields. Socioeconomic and biophysical interactions were then assessed. While the relationships described are specific to one watershed, the framework linking social factors, nutrient management, and resource degradation are more broadly applicable.

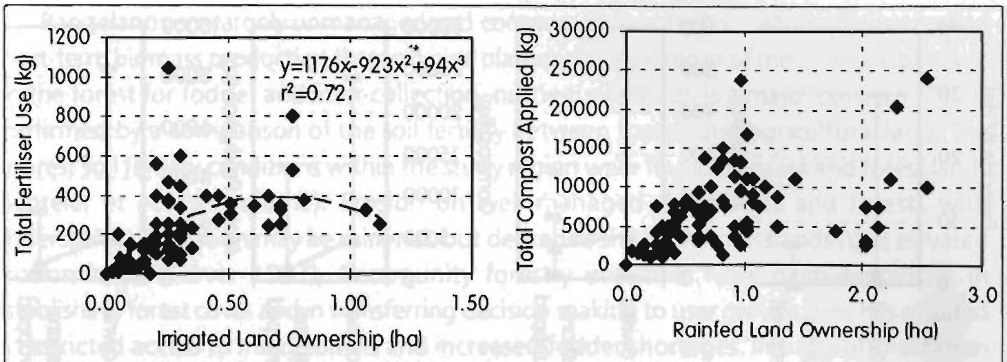
The aim of this paper is to document the following relationships between socioeconomic and biophysical factors:

- relationships between population growth, land holdings, and nutrient dynamics;
- the impact of share cropping on the use of agrochemicals;
- livestock dynamics and its relationship with fodder availability and nutrient management; and
- ethnic factors and their impact on nutrient use.

Relationships between Population Growth, Farm Size and Nutrient Supplies

Population growth, and the resultant increase in demand for food, places additional pressure on the resource base and specifically on soil resources. The per capita availability of land in the study area decreased from 0.26 ha in 1972 to 0.17 ha per capita in 1995, which is a greater decrease than for Nepal as a whole. Double and triple crop rotations are applied where water is available, but nutrient inputs may not be sufficient to sustain these intensive levels of production (Brown and Schreier this volume). Expansion of agriculture to marginal lands (Shrestha 1999) in response to population pressure has brought steeply sloping and low soil fertility lands under cultivation to provide additional food supplies. Recent declines in forest cover (Schreier *et al.* this volume) and reported shortages of forest products are indicative of the continuing pressure on forest resources, as are the increased demand for wood in house construction and brick making. Population growth, both locally and regionally, is a dominant factor driving land use dynamics within the study region, and the associated increase in demand for food, animal feed, and fuelwood results in increased biomass removal.

Nutrient inputs may vary with farm size as a result of both limited availability and economic constraints. Figures 113a-b show increasing total inputs with land ownership on both irrigated and rainfed land for small and medium sized farms, but decreasing inputs on larger farms. The relationships between land ownership, crop nutrient budgets, and soil fertility are summarised in Table 106. Significant differences in nutrient budgets (Brown and Schreier 1999) were noted between small, medium, and large farms and reflect both lower fertiliser inputs on large farms and the distribution of land types with farm size. Both small and large farms were dominated by rainfed land and displayed lower nutrient budgets. Households owning moderate amounts of land (1-2 ha) typically owned a mix of rainfed and irrigated land, applied the most fertiliser and compost to their fields, and had the best nutrient budgets. Differences in soil variables were also noted with farm size. Larger farms displayed



a) fertiliser use on irrigation land

b) compost use on rainfed land

Figure 113: **Nutrient Inputs with Farm Size**

Table 106: **Relationships Between Farm Size, Crop Nutrient Budgets, and Soil Fertility (median values and Mann Whitney U test)**

Farm Size			P-M-W Nutrient Budget (kg ha^{-1} furrow slice)		
			N-budget	P_2O_5-budget	Ca-budget
small	<1.0 ha	(n=20)	-24	-29	-16
medium	1.0-1.9 ha	(n=8)	-18	35	9
large	2.0-3.4 ha	(n=6)	-32	-43	-15
small vs. medium farms			+	++	++
medium vs. large farms			++	+	+
			Exch. Ca (cmol kg^{-1})	CEC (cmol kg^{-1})	C (%)
small	<1.0 ha	(n=20)	3.4	11	0.9
medium	1.0-1.9 ha	(n=8)	4.4	12	1.0
large	2.0-3.4 ha	(n=6)	3.3	9	0.8
medium vs. large farms				+	++

++ Significant differences between groups $_{\alpha}<0.05$
\+ Significant differences between groups $_{\alpha}<0.10$

lower exchangeable Ca, CEC, and %C, suggesting that there is a limited availability of organic matter on larger farms.

The Impact of Share Cropping on the Use of Agrochemicals

Share cropping was thought likely to have a negative impact on land management as a result of the uncertainty of land tenure arrangements and an unwillingness on the part of tenant farmers to invest in share-cropped land. Figure 114 shows the differences in inputs and production on owned and share-cropped land for rice and maize, the dominant crops grown on share-cropped irrigated and rainfed fields. Significant differences were noted between owned and share-cropped land in the total pesticide expenditures on rice fields, the total compost applied to maize fields, the total fertiliser used on both rice and maize fields, and in maize production. The differences in inputs were not significant on a per ha basis, but median pesticide, fertiliser, and compost values were all lower on share-cropped land. No difference was noted in rice yield between owned and share cropped fields, but maize

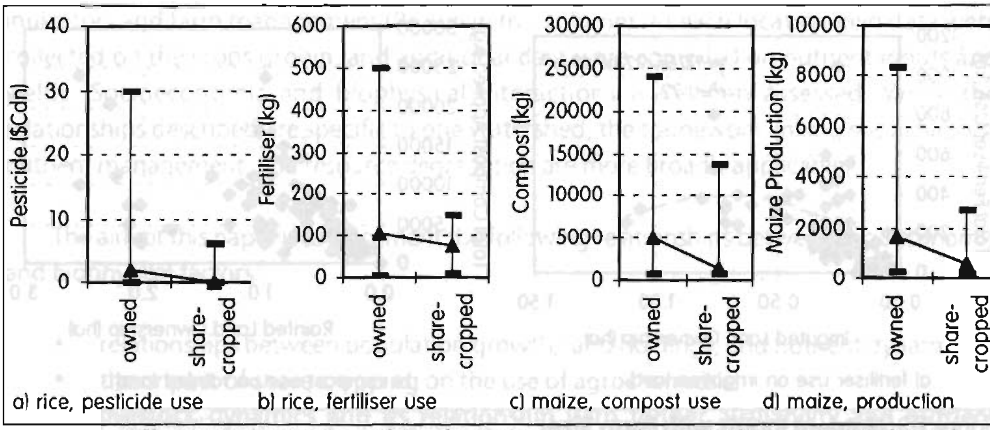


Figure 114: **Differences in Inputs and Production on Owned versus Share-cropped Land**

production on share-cropped fields was significantly lower. The variability in agrochemical use and crop production was substantially greater on owned versus share-cropped land, with the greatest inputs applied to owned land. While this limited data set is not conclusive, share-cropped fields on both irrigated and rainfed lands appeared to be less intensively managed than fields with secure land tenure.

Livestock Dynamics, Fodder Availability and Nutrient Management

The free grazing of animals, and the resultant removal of vegetation and trampling of the soil surface, have an impact on soil infiltration rates and erosion, and heavy grazing is responsible for much of the environmental degradation on government lands (Carson 1992). The proportions of stall-fed versus grazed animals during the wet and dry seasons reported by female farmers surveyed in 1989 and 1996 are shown in Figure 115. No change was noted in the proportion, of stall fed animals in the dry season between 1989 and 1996, but stall-feeding during the wet season increased significantly from 63 per cent in 1989 to 85 per cent in 1996. Female farmers were asked: "compared to five years ago, has the availability of grazing areas for your animals changed?" For the 1991-1996 period, 79 per cent responded that there were significantly fewer grazing areas available in 1996. Traditionally, the forests supplied 40 to 60 per cent of the total fodder, but pressure on the forest ecosystem from increasing human and livestock populations and agricultural encroachment has led to reduced availability of fodder, and a recent decrease in livestock holdings. The lack of fodder is in part due to the degradation of forest resources, as well as the new trend of reducing open access to the forests.

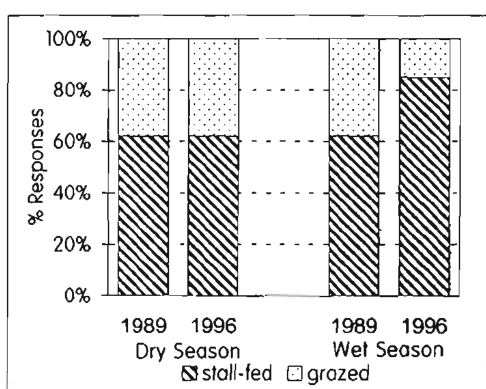


Figure 115: **Stall-feeding and Grazing Dynamics (n=27)**

Rangelands are largely unmanaged and community forestry has historically focused on short-term biomass production through pine plantations. As a result of the intensive pressure on the forest for fodder and litter collection, nutrient depletion is a major concern. This is confirmed by a comparison of the soil fertility between forests and agricultural land. The poorest soil fertility conditions within the study region were found on grass and forest lands (Schreier *et al.* this volume). Erosion on well managed rangelands and forests with understorey vegetation may be minimal, but degraded shrub and grasslands have elevated erosion rates (Carver 1997). Community forestry initiatives have been successful in establishing forest cover and in transferring decision making to user groups. This has resulted in restricted access to many forests and increased fodder shortages. Initially, afforestation efforts focused on pine plantations, but user group priorities have prompted the planting of fodder species such as *Dalbergia sissoo*. Options to improve dry season production on rangelands, such as the incorporation of legumes and deferred grazing, are constrained by the current land tenure system. The successful implementation of pasture management techniques will require the establishment of property rights either privately or communally, similar to the establishment of forest user groups. To date, the Department of Forestry has concentrated on planting trees and few resources have been focused on grasses.

Livestock type and holdings influence compost application to a household's farm land. Manure lost through grazing is decreasing as more households are stall feeding their livestock, and selling of manure is rare. The relative manure production potential of different types of livestock was represented by tropical livestock units (TLU). Livestock units are based on the N content of manure produced by a standard cow, which has a live weight in the tropics of between 200 and 350 kg. The factors for calculations relating cattle to other domesticated species are shown in Table 107. For example, one bullock is equivalent to five swine or 125 chickens (FAO 1975, Williamson and Payne 1978). The amount of compost applied to rainfed land showed a weak positive correlation with the number of TLUs owned, but only 10 per cent of households owned more than 10 TLU per ha. The lack of fodder has a significant impact on agriculture because manure is the main source of nutrients for many farmers.

Table 107: **Tropical Livestock Unit Equivalents**

Animal Type	TLU
Cattle – Bullock	1
Cattle – Cow	0.8
Cattle – Calf	0.4
Buffalo – Bull	1.2
Buffalo – Cow	1
Buffalo – Calf	0.5
Goat	0.1
Pig	0.2
Chicken	0.008
Duck	0.008

Caste and Ethnic Factors and Their Impact on Nutrient Use

A household's access to capital and other resources is influenced by caste and ethnic affiliation, thus compost, fertiliser, and pesticide use may vary between groups. The differences in the inputs used by high, medium, and low caste groups are presented in Table 108. On irrigated lands, high caste households applied more fertiliser while low caste households applied more compost suggesting affordability may limit the use of chemical fertilisers by low caste households. On rainfed fields, high caste households applied more

Table 108: Relationships between Caste/Ethnic Affiliation, Land Management, and Soil Fertility (median values and significant differences based on Mann Whitney U test).

		Caste			Significant Differences	
		High	Medium	Low	High vs. Med.	High vs. Low
Irrigated land (*khet*)						
Compost	(kg)	1313	0	1124	+	
	(kg ha^{-1})	2725	0	4786		
Fertiliser	(kg)	195	15	50	++	++
	(kg ha^{-1})	522	128	284	+	+
Pesticide	($ Cdn)	2	0	0		++
Rainfed land (*bari*)						
Compost	(kg)	7500	5160	2500		++
	(kg ha^{-1})	8346	7097	7259		
Fertiliser	(kg)	274	220	155	+	++
	(kg ha^{-1})	320	236	359		
Livestock						
	TLU	3.7	3.8	4.1		
	TLU ha^{-1}	3.6	3.9	5.7		++
Soil fertility						
base saturation	(%)	60	57	45		++
exch. Ca		3.9	3.0	3.2		++
PH		4.9	4.8	4.6		++

high caste = Brahmins (n=46); medium caste = Chhetri, Newar, Jogi and Magar (n=20);
low caste = Tamang, Danuwar, Kami and Sarki (n=19)
++ Significant differences between groups $_{\alpha}<0.05$
+ Significant differences between groups $_{\alpha}<0.10$

total fertiliser and compost, but no significant differences were found on a kg per ha basis. Lower caste households owned significantly more livestock on a TLU per ha basis than did high caste households and they distributed the compost differently. The low caste households concentrated their manure inputs on irrigated fields, whereas the high caste households applied more compost to rainfed fields. Differences in soil fertility were also noted between fields owned by high and low caste groups, with high caste households owning fields with better soil fertility conditions, but the differences might have reflected the sampling design. The fields in the sample were selected on the basis of soil fertility conditions, and more irrigated fields owned by high caste households were sampled. Recognizing the complexity of the Nepali class structure, caste and ethnic affiliation appear to influence nutrient management and thus, potentially, soil fertility conditions.

Conclusions

The socioeconomic factors driving nutrient dynamics and thus affecting soil fertility are not isolated but interrelated, and these factors may be influenced by resource degradation (Figure 116). Population growth, access to land, and cultural practices are closely tied to poverty. Poor families own smaller land holdings, typically own poorer quality land, and will be affected most by soil degradation. Population growth is driving land use change and thus altering nutrient flows within and between land uses. To meet the demands of a growing

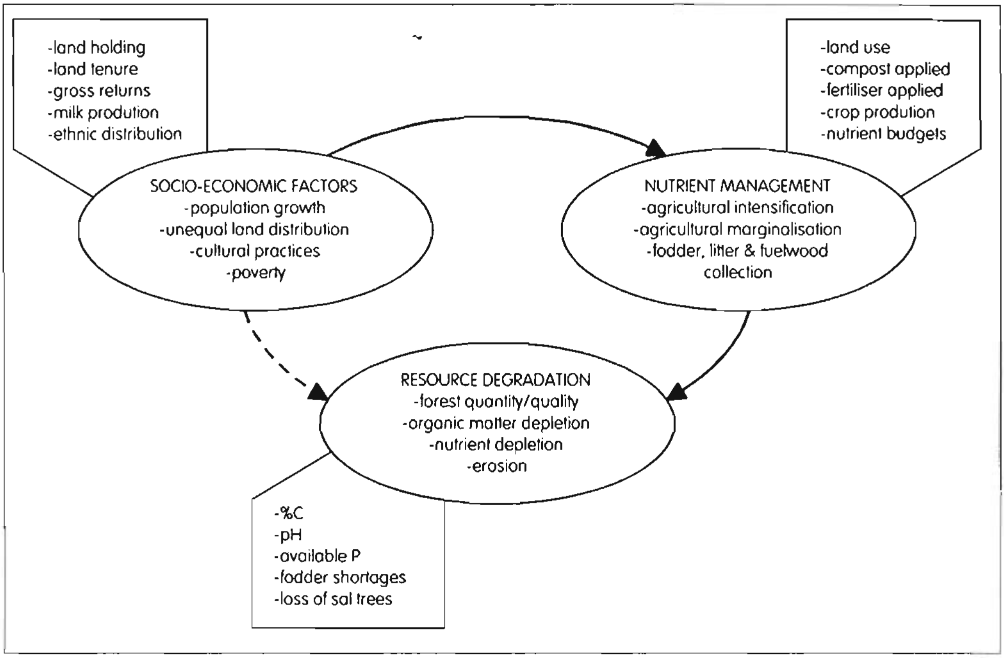


Figure 116: **Framework Linking Social Factors, Nutrient Management, and Resource Degradation.**

population, agriculture has been intensified and extended to marginal lands, and evidence of renewed deforestation is beginning to appear.

Access to land is a key factor driving nutrient management and influencing economic well-being. Land is the main agricultural asset of households in the study area, and irrigated land is more productive and provides greater opportunities for cash crop production than rainfed land. The poorest soil fertility conditions were found on common property lands (grassland, shrub, and forest). Share-cropped land was less intensively managed, and received lower inputs of chemical fertiliser, organic matter, and pesticides. Irrigated land received the most nutrient inputs per ha, showed the best nutrient budgets, and had the best overall soil fertility conditions.

While caste/ethnic distribution is not equivalent to class structure, differences were noted between Brahmins and other groups in the study area. Brahmins tended to use more agrochemicals, own more land, and own land with better soil fertility.

The economic well-being of households in the study area was strongly tied to the quantity and quality of land owned, and reflects a traditional versus a market-oriented agriculture (vegetable and milk production). Households with lower production returns, lower agricultural assets, and lower cash income tended to apply less nutrients to their fields. Equally, households growing vegetable crops (which have higher gross margins) may still have a negative impact on soil fertility as a result of the high nutrient demands of these crops. Farm management and nutrient dynamics are influenced by a combination of socioeconomic factors, but within this study area population growth and access to land were the two key components that affected resource conditions.

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Conclusions & Recommendations

PARDYP: A Regional Watershed Management Project of Global Importance with Strong Linkages to Chapter 13

Thomas Hofer
Forest Resources Division, FAO

Abstract

During the UNCED-Conference in Rio de Janeiro in 1992 the mountain areas of the world received special attention: Chapter 13 of Agenda 21 is entitled "Managing Fragile Ecosystems—Sustainable Mountain Development". In 1998 the UN General Assembly declared 2002 as the International Year of the Mountains (IYM). FAO is Task Manager for Chapter 13 as well as the lead agency for the International Year of the Mountains. The ICIMOD People and Resource Dynamics Project (PARDYP) is highly relevant for the global mountain agenda. Through its regional work in five watersheds, the comparative approaches, the interdisciplinary concept, the large range of stakeholders involved, and the search for best practices in the utilisation and development of resources in mountain watersheds, the project is making a significant contribution to the implementation of Chapter 13 and to the preparations for the celebration of the International Year of the Mountains. The continuation of PARDYP into a second phase with the same number of watersheds is highly recommended.

Chapter 13: An Introduction

What is Chapter 13?

In June 1992, the world summit on environment and development was held in Rio de Janeiro. The most important output of this conference was the Agenda 21, which was signed by 181 member countries. The document reflects a broad consensus that sustainable development towards a human future has to be based on partnership and can only be achieved through joint efforts in which ecological principles play a central role. Agenda 21 is described in 40 chapters (see Box 1); it highlights the key problems, formulates approaches in order to find solutions, and proposes strategies for action.

The mountain areas of the world receive particular attention in Agenda 21. The rationale for Chapter 13, entitled 'Managing Fragile Ecosystems – Sustainable Mountain Development' was as follows: "Mountains are an important source of water, energy and biological diversity. Furthermore they are a source of such key resources as minerals, forest products and agricultural products and of recreation. As a major ecosystem representing the complex and interrelated ecology of our planet, mountain environments are essential to the survival of the global ecosystem. Mountain ecosystems are, however, rapidly changing. They are susceptible to accelerated soil erosion, landslides and rapid loss of habitat and genetic resources. On the

BOX 1

The 40 chapters of Agenda 21 (Source: The United Nations 1992)

Chapter 1: Preamble

Section 1: Social and Economic Dimensions

Chapter 2: International cooperation to accelerate sustainable development in developing countries and related domestic policies
Chapter 3: Combating poverty
Chapter 4: Changing consumption patterns
Chapter 5: Demographic dynamics and sustainability
Chapter 6: Protecting and promoting of human health
Chapter 7: Promoting sustainable human settlement development
Chapter 8: Integrating environment and development in decision-making

Section 2: Conservation and Management of Resources for Development

Chapter 9: Protection of the atmosphere
Chapter 10: Integrated approach to the planning and management of land resources
Chapter 11: Combating deforestation
Chapter 12: Managing fragile ecosystems: Combating desertification and drought
Chapter 13: Managing fragile ecosystems: Sustainable mountain development
Chapter 14: Promoting sustainable agriculture and rural development
Chapter 15: Conservation of biological diversity
Chapter 16: Environmentally sound management of biotechnology
Chapter 17: Protection of the oceans, all kinds of seas including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources
Chapter 18: Protection of the quality and supply of freshwater resources: Application of integrated approaches to the development, management and use of water resources.
Chapter 19: Environmentally sound management of toxic chemicals, including prevention of illegal international traffic in toxic and dangerous products
Chapter 20: Environmentally sound management of hazardous wastes, including prevention of illegal international traffic in hazardous wastes
Chapter 21: Environmentally sound management of solid wastes and sewage-related issues
Chapter 22: Safe and environmentally sound management of radioactive wastes

Section 3: Strengthening the Role of major Groups

Chapter 23: Preamble
Chapter 24: Global action for women towards sustainable and equitable development
Chapter 25: Children and youth in sustainable development
Chapter 26: Recognising and strengthening the role of indigenous people and their communities
Chapter 27: Strengthening the role of non-governmental organisations: Partners for sustainable development
Chapter 28: Local authorities' initiatives in support of Agenda 21
Chapter 29: Strengthening the role of workers and their trade unions
Chapter 30: Strengthening the role of business and industry
Chapter 31: Scientific and technological community
Chapter 32: Strengthening the role of farmers

Cont ...

Section 4: Means of Implementation

Chapter 33: Financial resources and mechanisms
Chapter 34: Transfer of environmentally sound technology, cooperation and capacity-building
Chapter 35: Science for sustainable development
Chapter 36: Promoting education, public awareness and training
Chapter 37: National mechanisms and international cooperation for capacity-building in developing countries
Chapter 38: International institutional arrangements
Chapter 39: International legal instruments and mechanisms
Chapter 40: Information for decision-making

human side, there is widespread poverty among mountain inhabitants and loss of indigenous knowledge. As a result, most global mountain areas are experiencing environmental degradation. Hence, the proper management of mountain resources and socioeconomic development of the people deserves immediate action." (The United Nations 1992; some extracts from the original text of chapter 13 are presented in Box 2).

Within Agenda 21, Chapter 13 shows some unique features—unlike most of the other chapters, which have a strong sectoral orientation (see Box 1), the mountain chapter follows an integrated, holistic approach addressing all the driving forces active in a landscape like hydrology, geomorphology, erosion, hazards, agriculture, forestry, cultural diversity, biodiversity, recreation, trade, climate change, and participatory management of resources. Described thus, the implementation of Chapter 13 is particularly challenging and requires interdisciplinary approaches.

The Development of Chapter 13 from 1992 to 2002

The formulation of Chapter 13 in 1992 initiated a dynamic process of activities related to mountain issues of which just a few important elements are highlighted below. For a detailed account of this development we refer to the Task Managers Report (Price 1999).

- Under the umbrella of FAO, inter-governmental meetings were held in all continents to draw the attention of political authorities to the importance of mountain areas and their resources.
- A number of inter-agency meetings and NGO-consultations were organised.
- In 1995 a global Mountain Forum of NGOs was founded. It is coordinated by The Mountain Institute (TMI) in Virginia and currently has three regional nodes: the International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, for Asia; the Centro Internacional de la Papa (CIP), Lima, for Latin America; and the International Union for the Conservation of Nature (IUCN), Gland, for Europe. Regional nodes for North America and Africa will hopefully follow soon. These nodes have started to establish networks for the exchange of information and the learning process across continents.

BOX 2

Extracts from the original text of Chapter 13 **(Source: The United Nations 1992)**

CHAPTER 13: PROGRAMME AREAS

A. Generating and strengthening knowledge about the ecology and sustainable development of mountain ecosystems

Basis for action

13.4. Mountains are highly vulnerable to human and natural ecological imbalance. Mountains are the areas most sensitive to all climatic changes in the atmosphere. Specific information on ecology, natural resource potential and socioeconomic activities is essential. Mountain and hillside areas hold a rich variety of ecological systems. Because of their vertical dimensions, mountains create gradients of temperature, precipitation and insolation. A given mountain slope may include several climatic systems - such as tropical, subtropical, temperate and alpine - each of which represents a microcosm of a larger habitat diversity. There is, however, a lack of knowledge of mountain ecosystems. The creation of a global mountain database is therefore vital for launching programmes that contribute to the sustainable development of mountain ecosystems.

Objectives

13.5. The objectives of this programme area are:

- to undertake a survey of the different forms of soils, forest, water use, crop, plant and animal resources of mountain ecosystems, taking into account the work of existing international and regional organizations;
- to maintain and generate database and information systems to facilitate the integrated management and environmental assessment of mountain ecosystems, taking into account the work of existing international and regional organizations;
- to improve and build the existing land/water ecological knowledge base regarding technologies and agricultural and conservation practices in the mountain regions of the world, with the participation of local communities;
- to create and strengthen the communications network and information clearing-house for existing organizations concerned with mountain issues;
- to improve coordination of regional efforts to protect fragile mountain ecosystems through the consideration of appropriate mechanisms, including regional legal and other instruments;
- to generate information to establish databases and information systems to facilitate an evaluation of environmental risks and natural disasters in mountain ecosystems.

B. Promoting integrated watershed development and alternative livelihood opportunities

Basis for action

13.13. Nearly half of the world's population is affected in various ways by mountain ecology and the degradation of watershed areas. About 10 per cent of the Earth's population lives in mountain areas with higher slopes, while about 40 per cent occupies the adjacent medium- and lower-watershed areas. There are serious problems of ecological deterioration in these watershed areas. For example, in the hillside areas of the Andean countries of South America a large portion of the farming population is now faced with a rapid deterioration of land resources. Similarly, the mountain and upland areas of the Himalayas, South-East Asia and East and Central Africa,

cont ...

Box 2: cont.

which make vital contributions to agricultural production, are threatened by cultivation of marginal lands due to expanding population. In many areas this is accompanied by excessive livestock grazing, deforestation and loss of biomass cover.

13.14. Soil erosion can have a devastating impact on the vast numbers of rural people who depend on rainfed agriculture in the mountain and hillside areas. Poverty, unemployment, poor health and bad sanitation are widespread. Promoting integrated watershed development programmes through effective participation of local people is a key to preventing further ecological imbalance. An integrated approach is needed for conserving, upgrading and using the natural resource base of land, water, plant, animal and human resources. In addition, promoting alternative livelihood opportunities, particularly through development of employment schemes that increase the productive base, will have a significant role in improving the standard of living among the large rural population living in mountain ecosystems.

Objectives

13.15. The objectives of this programme area are:

- by the year 2000, to develop appropriate land-use planning and management for both arable and non-arable land in mountain-fed watershed areas to prevent soil erosion, increase biomass production and maintain the ecological balance;
- to promote income-generating activities, such as sustainable tourism, fisheries and environmentally sound mining, and to improve infrastructure and social services, in particular to protect the livelihoods of local communities and indigenous people;
- to develop technical and institutional arrangements for affected countries to mitigate the effects of natural disasters through hazard-prevention measures, risk zoning, early-warning systems, evacuation plans and emergency supplies.

- Through worldwide research initiatives, many projects and larger programmes with a significant regional collaboration in mountain areas have started.
- A number of key publications have been issued such as the volume 'Mountains of the World–a Global Priority' (Messerli and Ives 1997), a brochure focusing on the water resources of the world (Mountain Agenda 1998), and the proceedings of an e-mail conference on sacred mountains (TMI 1998).

In 1997, five years after UNCED, the UN Commission on Sustainable Development and the UN General Assembly held special meetings to review the implementation of Agenda 21. This conference clearly showed that the five years after Rio have been essential in successfully transmitting the message of the mountains as important areas of resources for the next century. More and more it was recognised that mountain areas have a global importance: mountains as resources for freshwater, as centres of biological diversity, as recreation areas, and as very sensitive indicators of climate change. It also recognised that the initiatives launched so far were very positive but not sufficient: the difficult challenge of implementing the results on a political level and in a concrete form within the framework of field projects lies ahead.

Through the initiative of the Republic of Kirgistan in proposing the year 2002 as the International Year of the Mountains (IYM), Chapter 13 received a new impetus. In 1998 the matter was presented to the Economic and Social Council of the United Nations (ECOSOC) where it was strongly supported. In November 1998 the proposal was discussed by the UN General Assembly and passed without vote. This decision is an outstanding chance and challenge for Chapter 13. It provides a unique opportunity to reinforce the long-term process begun at Rio of raising public awareness and ensuring adequate political, institutional, and financial commitments for concrete action on sustainable mountain development, that will hopefully last far beyond the year 2002. International organisations, NGOs, politicians, research institutions, donors, individuals, whoever is dealing with mountain related issues, are challenged to help shape this process and to bring about a highly successful IYM.

Chapter 13 and FAO

The programme on 'Watershed Management and Sustainable Mountain Development' has a long history in FAO and originally focused on purely technical aspects related to protection, forest management, and watershed hydrology. Over time, however, it has adopted a much more integrated view of watershed management and a more comprehensive approach to mountain conservation and development. This includes, for example, a greater emphasis on human development activities in addition to technical concerns such as soil and water conservation, and the recognition of the importance of the participation of local people in planning and implementing upland conservation and development activities. As a result of its long tradition and experience in watershed management and upland conservation, in 1993 FAO was given the Task Manager Role for Chapter 13. In addition, in the resolution of November 1998, the UN General Assembly declared FAO as the lead agency for the IYM.

Mountain-related Activities of FAO

With all these responsibilities, the FAO programme on watershed management and sustainable mountain development covers three main areas of work.

- Task Manager for Chapter 13 and Lead Agency for the IYM 2002

In addition to reporting responsibilities, the Task Manager role involves promoting and facilitating follow-up activity in the areas of information exchange, inter-agency consultation, catalysing joint activities and programmes, and developing common strategies. FAO has attempted to make the reporting process for Chapter 13—one of the primary task manager responsibilities—a collaborative effort by involving a number of other UN agencies, as well as NGOs, in the drafting and review of reports. This partnership approach has been greatly enhanced by the establishment of an ad hoc inter-agency group for Chapter 13 which first met in early 1994 and which has the aim of enhancing cooperation and collaboration in mountain development and conservation. The group is made up of various UN agencies and a number of international NGOs involved in mountain issues. The inclusion and active participation of organisations from outside the UN system has provided the opportunity for a wide range of views and perspectives to be considered in the on-going implementation of

Chapter 13, thus enabling a more balanced and equitable approach. Strengthening partnership, building capacity, and enhancing communication and information sharing have all been important aspects of FAO's work as Task Manager. In future a significant amount of FAO staff time and resources will be devoted to the preparation and observance of the International Year of the Mountains.

- The Normal Work Programme in Watershed Management and Sustainable Mountain Development

FAO's normal Mountain Programme has a number of important functions including generating and disseminating knowledge and information (Figure 117). The programme is involved, for example, in carrying out studies that aim at gaining a better understanding of various ecological, economic, and social processes. Developing and testing new technical guidelines, best practices and methodologies, and tools is another aspect of the programme's work. The FAO Conservation Guide series is one of the main vehicles used to achieve this. Conservation Guides have been published on a wide variety of topics, including both technical titles (e.g., 'Computer-assisted watershed planning and management') and titles more focused on socioeconomic issues (e.g., 'Income generation from non-wood forest products in upland conservation'). Training material aimed at building capacity is also developed for different levels of users, from policy makers to local communities. Enhanced capacity, at both local and national levels, is an important goal of the programme and an integral part of the approach to sustainable resource management and development in upland areas. Another aspect of the normal programme is the role FAO plays as the secretariat of the European Forestry Commission's Working Party on the Management of Mountain Watersheds—a body it helped establish in 1951. The group meets every two years to discuss technical issues relevant to watershed management in Europe.

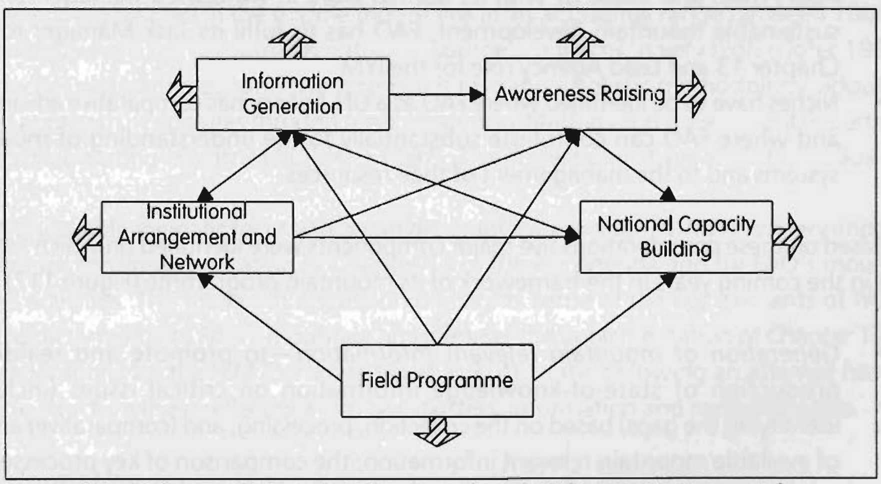

Figure 117: **Linkages (internal and external) with Other Institutions and Programme**

- Field Programme Activities

The operational side of FAO's work in sustainable mountain development and watershed management is an integral and essential part of the overall programme. Technical support is provided to a variety of field projects involved in natural resource conservation and management (like soil, water, forests, and biodiversity) and human development activities in mountain and upland areas. This is done, for example, through strengthening of local capacity, training in a variety of topics from appropriate technologies to participatory methodologies, and enhancing information exchange. FAO's Technical Cooperation among Developing Countries (TCDC) programme is allowing for greater South-South exchange in upland conservation and development work by facilitating the use of developing country experts in what can be a less costly and in some cases more appropriate alternative to international technical assistance coming primarily from the North.

Planning Towards the IYM: Some Preliminary Ideas of FAO

FAO is currently going through an intensive planning process to shape its programme on watershed management and sustainable mountain development for the years leading up to the IYM. The reflections are driven by the following.

- FAO's mountain programme has to be an open system. Its activities have to be carried out in close collaboration with other groups inside FAO and with key partners world-wide that are involved in mountain-related issues.
- The overall goal of all efforts made towards 2002 and beyond must be to make national governments aware of the importance of their mountain areas and to promote the implementation of strategies, best practices, and legislation for sustainable mountain development.
- Apart from and together with its normal work in watershed management and sustainable mountain development, FAO has to fulfil its Task Manager role for Chapter 13 and Lead Agency role for the IYM.
- Niches have to be identified where FAO as a UN Agency has comparative advantages and where FAO can contribute substantially to the understanding of mountain systems and to the management of their resources.

Based on these considerations five major components were identified on which FAO will focus in the coming years in the framework of its mountain programme (Figure 117).

- *Generation of mountain relevant information*—to promote and realise the production of state-of-knowledge information on critical issues (including identifying the gaps) based on the collection, processing, and (comparative) analysis of available mountain relevant information; the comparison of key processes, key problems, driving forces, and similar of different mountain systems of the world is a very important element

- *Institutional arrangement and networks*—to map out the institutional landscape (global and regional levels), to understand the activities and roles of major partners, to facilitate and service key processes and networks
- *Awareness raising, including preparation for observance of the International Year of the Mountains*—to raise the awareness of major stakeholders (including policy level, public administration, general public, NGOs, universities, schools) of the importance of sustainable mountain development and watershed management
- *National capacity building*—to make available substantive materials, tools, and training packages to member nations to help them plan and implement sustainable mountain development and watershed management programmes at national/sub-national level
- *Field programme support and collaboration*—to technically support watershed management relevant projects under the FAO field programme in the whole project cycle to collect, process, analyse, and disseminate their experiences

From March 10 to March 12 1999, the Inter-Agency Group on Chapter 13 will convene at FAO headquarters in Rome in order to start a coherent and well organised planning process for the IYM with principal collaborators in the Mountain Agenda. During this meeting, visions for the IYM will be brainstormed, priority issues defined, job sharing discussed, and a funding strategy initiated. FAO's current, very preliminary, visions for the celebration of the IYM are compiled in Box 3. It is hoped that the ideas will be further complemented, specified and modified during the Inter-Agency Meeting in March.

The People and Resource Dynamic Project (PARDYP) and Its Relevance for Chapter 13

PARDYP is an interdisciplinary watershed management project which operates in four of ICIMOD's partner countries along an east-west transect through the Himalayas. All the watersheds are located in the middle mountains in an altitudinal range between 1000 and 3000 masl, where the pressure on natural resources, in places, is very high (Hofer 1998). It approaches watershed dynamics and research through a holistic methodology, adopting a nested approach. It operates through focal research institutions and government departments in the collaborating countries (ICIMOD 1997). The project objectives are listed in Box 4.

With its wide thematic focus and broad geographical coverage, PARDYP is a very important element for the implementation of Chapter 13 of the Rio Agenda and for FAO's mountain-related activities. The following discussion highlights some of the key elements of PARDYP which directly feed into FAO's mountain programme, the implementation of Chapter 13, and the preparations for the IYM (compare Boxes 2, 3, 4). In the following an attempt has been made to structure these reflections into two clusters: information and methodologies.

Information

- PARDYP produces much disciplinary, in-depth information on a large number of issues, for example hydrology, meteorology, soil erosion, soil fertility, conservation,

BOX 3

Some Ideas Among Those Considered by the FAO Mountain Team for the Celebration of the International Year of the Mountains

Categories	Ideas for Specific Activities
Meetings, events	• International conference on mountain ecosystems • 'Food security in the mountains of the world' (topic for the World Food Day 2002) • 23rd session of the EFC Working Party • Training seminars: best practices in sustainable mountain development • Briefing workshop for journalists
Publications	• Definitions: mountains; sustainable mountain development • Conservation guides • Guidelines on best practices in sustainable mountain development • Guidelines for policy-makers • Mountains of the world in comparison: key processes, key problems, and driving forces • A collection of information material on mountains, either regionalised or world-wide or both
Awareness rising	• Film • TV/radio broadcasts • Essay competitions • Popularised brochures on key issues in mountain areas • Planning game on sustainable mountain development with different scenarios • Curricula for schools and universities
National capacity building	• Guidance to the formulation of appropriate mountain policy and legislation • Guidelines for mapping out the institutional landscape • Indicative mountain development programme; operational review of Agenda 21 Chapter 13
Field activities	• Pilot project on highland-lowland interactions established and in operation • Network of watershed management projects linked world-wide, common ideas coordinated

rehabilitation of degraded areas, agronomic systems and initiatives, horticulture, forestry, cooperation, and people's participation. The generation of a solid knowledge base is a very strong focus in the original text of Chapter 13.

- Through its holistic approach PARDYP produces a lot of knowledge regarding linkages between different elements and driving forces in a watershed: for example erosion, and sediment and nutrient loss on a plot as a function of rainfall, slope, aspect, elevation, soil characteristics, crop type, land preparation and management, season, indigenous practices for prevention of excessive surface runoff, and soil

BOX 4

The Objectives of PARDYP

Objectives

The main objectives of this programme will be to develop a comprehensive monitoring system for people and resource dynamics in selected watersheds of the Hindu Kush-Himalayas, to develop a better understanding of these processes, and to develop guidelines for policies and programmes in this field.

The specific objectives of the project are:

- to generate relevant and representative information and technologies about water balance and sediment transport related to degradation on a watershed basis;
- to identify technologies and strategies to improve soil fertility and to control erosion and degradation processes in a farming systems' approach;
- to generate socioeconomic information on resource management and degradation;
- to systematically apply community-based participatory generation, testing, and evaluation of natural resources' management strategies and technology;
- to strengthen the capacity of project partners;
- to make accessible to stakeholders relevant project information on project outputs;
- to effectively and efficiently manage the project as a regional collaborative research and development undertaking.

(Sources: ICIMOD 1996; ICIMOD 1998)

loss. This knowledge base is particularly well developed in the Jhikhu Khola watershed of Nepal, in which the activities go as far back as 1989 (see also Schreier *et al.* 1995; Brown 1997; Carver 1997).

- In each watershed a unique nested approach is applied, quite different to the approach used in other watershed management projects. Information is generated for the plot level, for the household/farm level, for the sub-catchment level, and for the whole watershed. This approach provides information on how results are modified and how driving forces change at different scales.
- Through project work in five watersheds in different ecological zones of the Himalayas, and the approach of using common methodologies, PARDYP provides a lot of scope for comparison over rather long distances. A lot of information will be generated about commonalities and differences, about key processes, about driving forces, and about general as well as regionally specific strategies and best practices for the rehabilitation of degraded lands and for sustainable use of the resources in the watersheds.
- The project has a very strong field base. The information generated in the project is primary, original data collected in the field and not data compiled from secondary sources.

Methodologies

Apart from the large amount of information relevant to Chapter 13 that PARDYP is creating, many methodological aspects are being developed through the unique set up of the project. Such methodological experiences are as important for Chapter 13 as information.

- The strongly interdisciplinary approach has considerable scope and potential for methodological achievements: how can the large variety of physical and socioeconomic different elements active within a watershed be brought together, be linked together? How can work in complex, interdisciplinary projects be best and most efficiently distributed and coordinated? How best can work in the different disciplines be focused in order to make sure that the results fully contribute to the overall aims and the synthesis of the project and do not drift away? How can findings that are based on measurements of parameters (water flow, suspended sediments, soil erosion, rainfall) be validated and complemented with the experiences of the people acting in this environment and using the resources?
- The second major methodological challenge is to make good use of the nested approach. How can the information at the different scales be linked together? To what extent can results obtained from analysis on the plot or farm level be extrapolated to the whole watershed? What methodological problems arise while doing such exercises and how can they be solved?
- Little methodological experience is available at present for the comparison of watersheds. PARDYP also offers good scope for significant achievements in this area. What are the procedures to compare different watersheds with each other? On what level of aggregation or generalisation has the comparison to be carried out? What are the filtering mechanisms? If these exercises are carried out within PARDYP successfully, then the results will be a very important contribution to the global mountain programme—which is challenged by the comparison of different mountain systems of the world with regard to the key processes, key problems, and driving forces.
- From the beginning, the project set up included a large variety of players: local people in the field, local institutions, regional and national institutions, researchers, NGOs, development workers, and donors. This type of collaboration again has considerable potential for significant methodological achievements. How can local knowledge and experiences best be used for the development of overall strategies and best practices for sustainable management of the resources in a watershed? How can overall strategies be translated by different intermediaries into concrete action at the local level? What are the most successful and efficient approaches to raise awareness among the different stakeholders about the importance of sustainable management of resources in a mountainous watershed?

Conclusions

All the elements highlighted above, which are key features of the PARDYP-project, have a direct link to the requirements of Chapter 13 (see Box 2) and are a significant contribution to FAO's mountain programme. The regional set up, the comparative approaches, the interdisciplinary concept, the large range of stakeholders involved, and the search for best practices in the utilisation and development of the resources, these are all unique features that fit into the central requirements of the Mountain Agenda. It is obvious, therefore, that a successful completion of the first phase of PARDYP and an equally successful second phase will contribute significantly to the preparation and celebration of the IYM as well as to those processes reaching far beyond 2002.

The close contact of PARDYP with FAO's mountain programme and FAO as Task Manager of Chapter 13 would be very desirable: FAO can only fulfil its mandate in close collaboration with other institutions involved in mountain related issues. The formulation of strategies, of best practices on sustainable mountain development, and of guidelines for policy legislation (Figure 117) will only be credible if they can be based on solid, concrete experiences from case studies in the field. These experiences may come from FAO field programmes, but they may also be imported from non-FAO projects, PARDYP being a very important example. On the other hand FAO can provide technical assistance to PARDYP if need be.

Purposely, in the above discussion a somewhat idealised picture has been given of PARDYP in order to highlight the significant relevance of the project for the global mountain agenda. It is very clear that the challenges, the expectations, and the requirements with which PARDYP is confronted are enormous. It is clear, too, that in the first phase not all of the challenges could be met in the same successful way and not each country team can tell the same success story. However, from the perspective of FAO it is essential that PARDYP continues at least into a second phase. The thematic and institutional set up of the project are clearly long-term oriented. Only in the next project phase can certain elements properly mature like, for example, the identification of the most successful strategies for rehabilitation of degraded lands, or the comparison of different watersheds. In addition, it is clear that the project has to continue with at least the existing set up of five watersheds. A reduction in the number of test areas for the second phase would destroy the unique set up of PARDYP and "degrade" PARDYP to a traditional watershed management project of which a large number already exist.

A number of hopes and requests for the next phase of PARDYP are listed below.

- It is hoped that the relevance of PARDYP to Chapter 13 has been sufficiently well highlighted, and that the title of 'PARDYP: a regional watershed management project of global importance' has been justified. This emphasises the high responsibility and the relevance of the work of each individual actor in the project. In turn it is hoped that this will motivate each country team to make a maximum contribution to achieving success during PARDYP Phase II and, where necessary, to catch up with the state of work in other test areas.
- It is strongly recommended that the high degree of interdisciplinarity and the strong field orientation of the project be maintained.
- It is recommended that particular emphasis is given to a synthesis of results and to the extension and implementation of results during Phase II.

- The comparability of methods used in the different watersheds should also be given particular attention.

As Task Manager for Chapter 13, FAO would like to convey its best wishes to the PARDYP-team for a successful continuation of the project!

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Conclusions

Richard Allen[1], Hans Schreier[2], Pravakar B. Shah[1], and Sandra Brown[2]
[1]International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal
[2]Institute for Resources and Environment, University of British Columbia, Vancouver, Canada

The watershed projects in Nepal have undergone significant evolution over the past few years with the move from a basic science approach to a more community-based participatory approach. The main issues that have been addressed in PARDYP-Nepal are listed in Table 109, which includes the methods used to address the issues and the indicators selected to determine the extent of the problem.

Many of these research activities were carried out in an interdisciplinary manner and with participation of both men and women farmers. Because the project benefited from long-term support, it is now possible to look at the overall dynamics of the watershed system in terms of water, nutrient, and biomass balances. The results show a somewhat disturbing pattern. The increases in population growth are greater than the innovations and productivity gains by the farmers. This is leading many male farmers to consider seeking off-farm jobs, which increases the workload for women since they remain behind to tend the farm. Also, fodder and fuelwood shortages are increasing because there are insufficient resources to sustain the population. Similarly, soil nutrient pools are declining and water shortages during the dry season are increasing. Efforts to introduce cash crops (potatoes and tomatoes) and the marketing of milk have the potential for improving household economics. However, with these developments come new problems such as excessive use of pesticides, insufficient nutrient additions, soil acidification as a result of using primarily acid producing fertilisers, and increased workload.

Table 110 shows some of the constraints that face the farmers in the Nepalese watersheds. It also contains information on the lessons learned and on the opportunities that can be addressed in future research activities during Phase II. Emphasis will be placed on opportunities, the specific research programmes are outlined in the Phase II proposal. To date, although not all findings are completely applicable in all study areas, the following conclusions can be drawn from the research in the PARDYP watersheds.

Water Issues

The problems. Water shortages are widespread during the dry season and include shortages for irrigation as well as for drinking water supplies. This is confirmed on the basis

Table 109: **Issues Addressed, Methods Applied, and Indicators used in Researching the Nepali Watersheds**

Issues	Methods Used	Indicators Used
Population pressure leading to land use intensification, land use changes	PRA and RRA surveys Airphoto, satellite image, and GIS analysis	Distribution of land holdings Population density Crop rotation and biomass production Changes in land use (GIS based)
Drinking and irrigation water shortages	PRA surveys, rainfall/stream flow, and irrigation water evaluation	Extent of water shortages Water quality, water harvesting effectiveness
Widespread soil nutrient deficiencies	Participatory (gender sensitive) soil fertility survey	Soil C, P, Ca, and pH values
Forest degradation, fodder, and fuelwood shortages	PRA surveys and intensive monitoring of forest plots	Forest cover and forest quality changes Species biodiversity measurements
Poor agricultural productivity due to insufficient inputs	PRA, biomass surveys, nutrient deficits	Nutrient budgets
Pesticide problems	PRA survey on pesticide use	Type and number of applications/crop
Socio-economic problems due to resource deficiencies	PRA, economic evaluations, off farm labour assessment	Gross margins Workload
Gender inequities	PRA, women user group surveys	Workload of women, resource access (common property and community forests)
Degraded land rehabilitation	Planting N-fixing fodder trees, legumes, and grasses	Biomass surveys, monitoring soil nutrient changes
Alternative energy sources	Demonstration fair	Acceptance of fuel efficient stoves
Marketing of milk and cash crops	PRA, milk survey, cash crops survey	Income, production and consumption, profitability
Sediment problems (erosion, transport, and impact)	Sediment monitoring and surveys	Mass balance, sediment nutrients
Training and extension	Participatory demonstration	Number of participants and level of interest
Communication	GIS and multi-media tools	Distribution of CD-ROMs

of stream flow measurements as well as from participatory surveys in both watersheds. The reasons for this include the continued expansion and intensification of agriculture and hence water demand due to rapid increases in population (growth and immigration), higher aspirations, and growing need for cash.

The initiatives. During Phase I, two water harvesting systems were constructed and are currently being tested to determine collection efficiency and irrigation options during the dry season. A water quality monitoring programme was started in 1998 in Nepal to determine potential water pollution problems, and an inventory of freshwater springs was also initiated in China, Pakistan, and Nepal. Irrigation system efficiencies are being tested and alternative application methods will be examined.

Table 110: **Issues, Constraints, Lessons Learned, and Opportunities for Research**

Issues	Constraints	Lessons learned	Opportunities
Water	Rainfall/runoff relationships	Imperviousness	Reduce surface runoff
	Sediment dynamics	Hydropower and irrigation	Better site selection for projects
	Water availability for irrigation	Dry season shortages	Water harvesting
	Drinking water supplies	Health problems	Improving wells
	Climatic variability	Coping with extreme events	Improve water planning
Agriculture	Land available for intensive agriculture	Shrinking land supply	Improve crop rotations
	Insufficient inputs	Make nutrient budgets	Balance inputs
	Too much use of pesticides	Health, need for extension	Natural pesticides, Integrated pest management
	High labour requirements	Workload for women	Reduce time needed for, and better sharing of, major daily tasks
	Water supply shortages	Insufficient irrigation	Improve irrigation management
	Use of marginal land	Erosion & soil fertility	Cover crops, legumes
	High labour/marginal returns	High risk crop problem	Focus on N-fodder
	Agricultural biodiversity	Risk with single crop	Diversity, high value crops
Forestry	Integration with agriculture	Interdependence	Systems approach
	High fuel and fodder demand	Political/legal problems	Community forestry
	Biodiversity	Pine plantation issue	Native N-fixing trees
	Forest policy	Revision of practices	Innovative management
	Litter demand	Selective use of litter	Improve diversity and management
Soil fertility	Nutrient deficiencies	Negative nutrient budgets	Balanced nutrient budget
	Carbon balance	Decline affecting quality	Compost/green manure
	Soil acidification	Better use of fertiliser/manure	Local lime & organic matter
	Microbial issues	Lack of microbial activity	Improve mycorrhizal fungi
Rehabilitation	Degraded sites rehabilitation	Slow & difficult process	Use selected native plants
Socioeconomics	Workload of women	Market crops = more work	Improve fodder, water supply
	Limited markets & demand	Poor demand analysis	Economic (cost benefit) analyses
	Poor infrastructure	Poor road access & network	Conflict resolution/ stake-holder involvement
	Alternative energy	Food processing	NGO involvement
Policy	Lack of extension service	Farmers get little advice	Change policy & services
	Alternative employment	Diversify economy	Niche products, tourism, development
Population	High growth rate	Immigration/market economy	Improve education
Climate change	Uncertainty and extremes	Creates hardship	Diversify and conserve
Integration	Interrelationships	Systems approach	Modelling
Capacity building	Appropriate people	Compatibility	Regional training
Communication	Training opportunities, access to technology	Effective multi-media tools	Local language pamphlets, Internet, distance edu.

Nutrient Issues

The problems. Soil nutrient deficiencies are widespread and have been well documented by the project in India, China, and Nepal. The primary problems include: a) lack of organic matter as a result of insufficient access to animal and green manure; b) high soil acidification due to the presence of acidic bedrock, the use of acid producing fertilisers, and the addition of pine litter to compost; c) low availability of phosphorus as a result of poor P distribution in bedrock, acidic soil conditions, and the presence of high quantities of amorphous Fe and Al in the red soils; and d) the lack of base cations as a result of leaching enhanced by the acidic soil conditions. In Nepal, nutrient deficiencies have been determined on the basis of soil sample analysis, by determining nutrient budgets for the main crops and cropping systems of 75 farmers, and by PRA methods.

The initiatives. Soil fertility improvement trials are underway with a focus on improving the organic matter content by addition of green manure, by introducing N-fixing trees and leguminous crops into the farming and forestry system, and by improving the composting processes at the farm level. The acidification problem is addressed by the addition of lime (from local limestone sources) to the soil, by discouraging the use of pine litter in composting, and by adding base cations to the soils through selective plant litter addition.

Erosion and Sedimentation Issues

The problems. From longer term data in the Nepal watersheds, erosion losses in rainfed agriculture are known to occur during the pre-monsoon season when the soils are barren and unprotected as a result of the lack of vegetation cover. Up to 80 per cent of the annual soil losses occur during this period. Sediments clog up irrigation systems, create problems for downstream hydropower development, and accentuate flooding. More than half of the annual sediments originate from degraded sites, which in spatial terms make up a relatively small portion of the watersheds in Nepal.

The initiatives. Experiments are under way to determine what kind of crop cover could be incorporated into the rotation system to assure that the soils are covered by vegetation at this critical time. Reclamation and rehabilitation experiments are taking place on degraded sites to establish a vegetative cover that stabilises the slopes, reduces erosion, improves the soil productivity, and generates biomass that can be used for fodder.

Forest Resource Management Issues

The problems. The pressure on forest resources is enormous in most of the PARDYP watersheds. In Nepal, based on a historic GIS analysis, it was found that the forest cover has undergone cycles of degradation and rehabilitation. Unfortunately these cycles are moving in a downward direction. This was confirmed by test plot experiments and PRA surveys of user groups, which revealed that shortages of fodder and firewood are increasing at a time when the responsibility for managing the forests is being turned over to communities. In all watersheds, restricted access is essential to ensure forest recovery, but this places additional hardship on women in households with small land holdings since they are now even more deprived of fodder. A loss of trees, decline in biodiversity, and long term decline of soil nutrients in the forest soils has also been documented.

The initiatives. Experiments to improve grass production and to introduce rotational management in the forests are under way. The introduction of legumes into the forest grass cover is being tested. Introducing native nitrogen-fixing fodder trees into the community forests is being promoted because simple forest closure will result in a much slower natural recovery. Pressure has been put on forest managers to abandon the standard afforestation policy of establishing chir pine plantations. Instead demonstration sites have been set up and nurseries have been developed that promote the use of native nitrogen fixing fodder species.

Gender Issues

The problems. The workload of women is excessive and in Nepal it is increasing with the introduction of cash crops, such as potatoes and tomatoes, and with the new opportunities for marketing milk. As the forest and water resources degrade, forest access and fuelwood and fodder collection time increase. Also, the opportunities for off-farm labour are significantly better for males. Hence women often manage the farm while husbands seek off-farm work. In all watersheds, current farming systems are inherently labour intensive and all the above-mentioned trends are increasing the workload of women. Traditional, cultural, and religious practices play a large role in the unequal sharing of the workload, which further complicates the issue.

The initiatives. In all watersheds, training and education programmes are being conducted with women groups to assist in afforestation efforts. Demonstration sites have been set up to show how grass production can be improved in the forest, and how the use of fuelwood can be made more efficient by the introduction of fuel-efficient stoves. Efforts are also being made to improve drinking water supplies. A strong push is being made to extend female education programmes and to advocate that girls remain in school at least as long as the boys. Education of women is advocated to improve population control practices, to give women better skills in financial matters, and to introduce female members to jobs in the forestry and agricultural sectors.

Agricultural Production Issues

The problems. Crop yields are stagnating, intensification has reached average annual rotation levels of 2.7 crops per year, and many crops are not responding well to additional inputs of chemical fertilisers. In Nepal, the overuse of pesticides on newly introduced cash crops (potatoes and tomatoes) is causing health concerns, and the profitability and food security for staple crops is poor. In all watersheds, land holdings for the great majority are small, agricultural expansion is limited (only marginal lands on steep slopes and degraded sites are not currently used), and further intensification is difficult due to water shortages during the critical dry period and insufficient access to nutrients (manure and chemical fertilisers).

The initiatives. In Nepal, the excessive use of pesticides on tomatoes and potatoes has been documented through PRA analysis and collaboration with NGO's. Health authorities and government agencies in charge of extension have been encouraged to educate communities in the proper use of pesticides. Efforts are also underway to document the effect and use of indigenous pest control practices and integrated pest management. Integrated nutrient management (combining manure, chemical fertilisers, and nitrogen fixing crops) is also promoted.

Socioeconomic Issues

The problems. Income and food sufficiency is inadequate for 2/3 of the farmers in the watersheds. Given the large population growths (over 2% in all watersheds) and the very small land holdings it is difficult to improve the livelihood of the inhabitants. Alternative employment is scarce and cash cropping requires additional labour. The income from cash crops and, in Nepal, milk production, is attracting immigrant labourers, but the markets are poorly identified, and demand and transport to markets are uncertain as a result of the poor infrastructure and conflicting policies.

The initiatives. Opportunities and constraints have been identified for milk production in the Jhikhu Khola, for floriculture in India, and for tea in China, India, and Pakistan. Alternatives to single cash crop production are being explored. The emphasis on vegetable production is being examined from an economic, workload, and agrobiodiversity point of view. A study on farm gross margins shows that basic staple crop production is in many cases a negative economic proposition and the introduction of alternative crops into the crop rotation is one of the options to consider.

Communication Issues

The problems. Scientific information has not been disseminated to farmers in an effective manner and better methods are needed before farmers will adopt new technologies and management practices. In addition, not enough information on the status and rate of degradation in water and natural resource management is reaching the policy and decision-makers. Alternative practices that are less fuel, labour, water, and nutrient demanding have not been described and promoted in an effective manner.

The initiatives. Leaflets in national languages are now being produced to take concrete positive messages to farmers via local CBO groups and NGOs. Hypermedia CD-ROM techniques are used to present the results of the research to policy makers and donor agencies in the hope that greater attention will be drawn to the key problems of soil fertility, water shortages, pollution problems, and fodder shortages. On-farm interventions are being carried out and demonstration sites introduced to improve experiments and introduce management practices that take into account the constraints faced by the farmers. In this way successful on-farm initiatives are more likely to spread and become more widely acceptable.

Participating Countries of the Hindu Kush-Himalayan Region

- Afghanistan
- Bangladesh
- Bhutan
- China
- India
- Myanmar
- Nepal
- Pakistan

International Centre for Integrated Mountain Development

4/80 Jawalakhel, GPO Box 3226 Kathmandu, Nepal

Telephone
+977 1 525313
Fax
+977 1 524509
+977 1 536747

e-mail
distri@icimod.org.np
Web site
http://www.icimod.org.sg
Cable
ICIMOD NEPAL