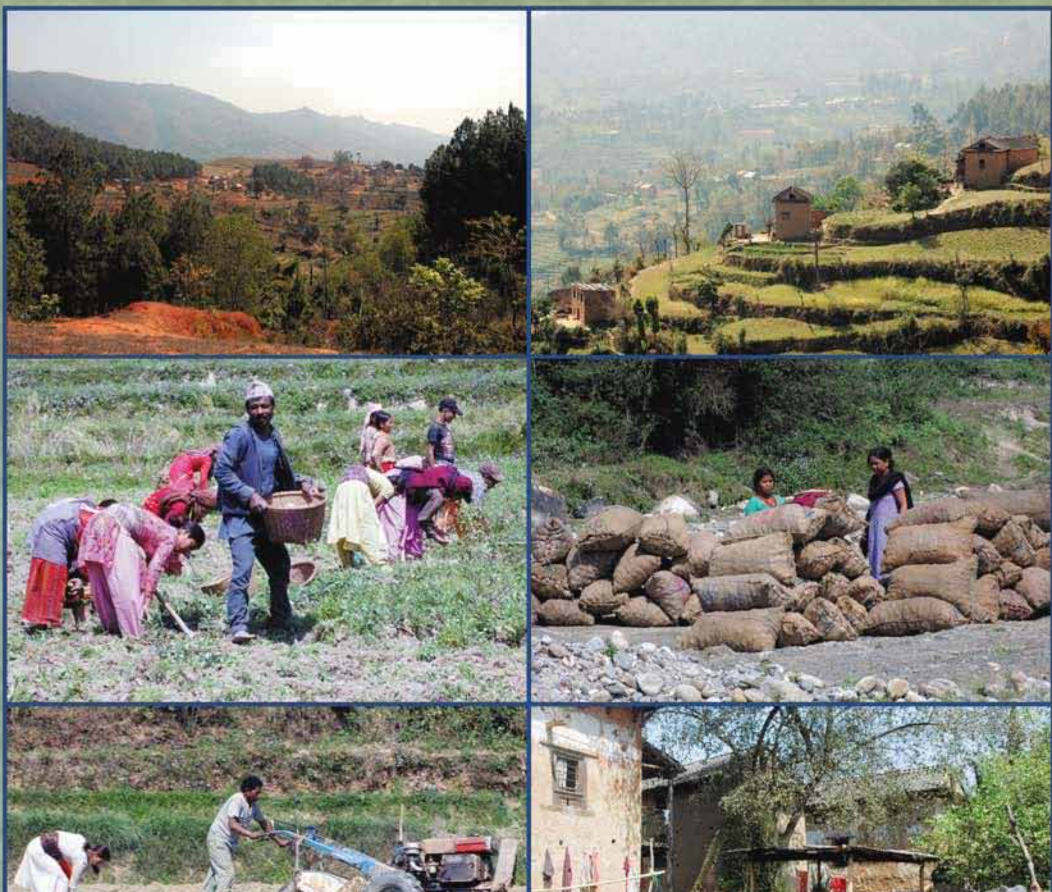
Good Practices in Watershed Management

Lessons Learned in the Mid Hills of Nepal



About ICIMOD

The **International Centre for Integrated Mountain Development** (ICIMOD) is an independent 'Mountain Learning and Knowledge Centre' serving the eight countries of the Hindu Kush-Himalayas – Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal and Pakistan – and the global mountain community. Founded in 1983, ICIMOD is based in Kathmandu, Nepal, and brings together a partnership of regional member countries, partner institutions, and donors with a commitment for development action to secure a better future for the people and environment of the extended Himalayan region. ICIMOD's activities are supported by its core programme donors: the governments of Austria, Denmark, Germany, Netherlands, Norway, Switzerland, and its regional member countries, along with over thirty project co–financing donors. The primary objective of the Centre is to promote the development of an economically and environmentally sound mountain ecosystem and to improve the living standards of mountain populations.

Good Practices in Watershed Management

Lessons Learned in the Mid Hills of Nepal

People and Resource Dynamics Project – Nepal Team

International Centre for Integrated Mountain Development (ICIMOD)
Kathmandu, Nepal
March 2007

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

ISBN 978 92 9115 017 5

Editorial Team
Matthew Zalichin (Consultant Editor)
A. Beatrice Murray (Senior Editor)
Dharma R. Maharjan (Technical Support; and Design Layout)

Photo credits
All photos from PARDYP Nepal

Printed and bound in Nepal by
Quality Printers (Pvt) Ltd.
Kathmandu

The PARDYP Nepal Team

Anil Shrestha	Sociologist
Bandana Prajapati	On-farm coordinator
Bhawani S. Dongol	Research Associate
Bhuban Shrestha	Country Coordinator
Birendra Raj Adhikari	Hydro-meteorologist
Diwakar Maskey	Social Forester
Gopal Nakarmi	Geologist
Juerg Merz	Hydrologist
Keshar Man Sthapit	Country Coordinator
Madhav P. Dhakal	Research Associate
Madhav Pandey	Social Forester
Megh Rajani Rai	Sociologist
Prabhakar Bickram Shah	Country Coordinator
Pradeep Man Dangol	Research Associate
Prem Raj Neupane	Agronomist
Radha Karki	Social Forester
Smita Shrestha	Water Management Assistant
Yamuna Ghale	Agronomist

Contents

Foreword

The middle altitudes of the Himalayan region are intensively used and highly populated. The management of land, forest and water in these areas is the basis of mountain livelihoods. The land use practices employed depend on the complex dynamics of water-land relationships as well as the diverse social, institutional, and economic conditions found throughout the region. These practices have profound impacts on the productivity and sustainability of mountain watersheds as well as the millions living downstream.

The importance of understanding the dynamics and relationships between socio-economic and biophysical aspects of middle altitude mountain watersheds led ICIMOD to amalgamate earlier projects on the rehabilitation of degraded land and mountain natural resources into the 'People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas' project (PARDYP) in 1996 based on experience in Nepal. The Swiss Agency for Development and Cooperation (SDC) joined the International Development Research Centre (IDRC, Canada) in providing funding and intellectual support.

PARDYP illustrates the collaborative regional approach taken by ICIMOD. Research and the daily management of project sites were undertaken by the collaborating focal institutions in China, India, Nepal, and Pakistan. The participating scientists from these countries were the project's researchers. Technical backstopping was provided by specialists from the Universities of British Columbia (Canada), Zurich and Berne (Switzerland).

This publication documents the experience and lessons learned from the PARDYP-Nepal sites. Detailed hydro-meteorological data, together with land use related data, were collected and analysed to increase understanding of topics such as land degradation and water management. The results have been archived for future research use on climate change, land use dynamics, and sustainable mountain agriculture and are partly presented here. Many of the easy-to-implement technological options for improved livelihoods and community-based management of natural resources developed by the project are relevant across the middle altitude zones of the Himalayan region and are also presented here. The document also addresses many of the questions commonly asked about managing mountain natural resources and forms the basis for developing the next generation of watershed management programmes.

I hope that the publication will be useful to extension workers, planners, development specialists, researchers, and policy makers in national institutions, NGOs, and donor agencies working on watershed management and mountain agriculture. I would like to extend my sincere gratitude to SDC, IDRC and ICIMOD core donors for their generous financial support.

J. Gabriel Campbell Ph.D
Director General, ICIMOD

Acknowledgements

This report was written by a group of PARDYP-Nepal staff. Keshar Man Sthapit led the preparation. Pradeep Dangol contributed the chapter on ‘Soil Loss and Runoff Monitoring’; Bhawani Dongol contributed the chapters on ‘Water Scarcity and Water Quality’; Madhav Dhakal contributed the section on management options in the ‘Water Scarcity’ chapter, the ‘On Farm’ chapter, and the case studies in the ‘Access’ chapter; and Anil Shrestha contributed the institutions section of the ‘Access’ chapter.

Our heartfelt thanks go to all the station observers who took the hydro-meteorological measurements, the field staff involved in the supervision and implementation of the field activities, and the farmers involved in implementing the activities. Thanks also go to all the professional staff who served PARDYP in the many research studies and implementation of field activities, and all the students who carried out research in the watersheds in part fulfilment of their academic studies (B.Sc., M.Sc., and Ph.D.).

This document follows the format and questionnaires developed at a workshop with participants from three of the PARDYP country teams (India, Nepal, and Pakistan), the regional support team, and a technical backstopping team (from the University of Berne). Thanks go to all the members of these teams, especially Dr. Rolf Weingartner.

The support of different line agencies, especially the Department of Soil Conservation and Watershed Management, Spice Crop Development Centre, District Forest Office, District Agriculture Office, and Divisional Irrigation Office, is gratefully acknowledged.

Special thanks go to Roger White, Sanjeev Bhuchar, Isabelle Providoli and other ICIMOD staff for their thorough review and valuable suggestions, and to Eklabya Sharma for his support in preparing the document. Thanks to all participants at the ‘Dissemination Workshop on Lessons Learned under PARDYP’ held on 25 May 2006 at Dhulikhel, Kabhre District for their comments and suggestions, and especially Gregor Doppmann for his comments.

Last but not least, we thank the Publications Unit in the IMCO Division of ICIMOD for the preparation of the book in its final form.

People and Resource Dynamics Project-Nepal (PARDYP)
ICIMOD, 2006

Executive Summary

From September 1996 to June 2006, ICIMOD conducted research to investigate the dynamics and relationships between socioeconomic and natural resources' factors in five middle-mountain watersheds across the Himalayas (in China, India, Nepal, and Pakistan). The People and Resource Dynamics Project (PARDYP) in Mountain Watersheds of the Hindu Kush-Himalayas was funded by the Swiss Agency for Development and Cooperation (SDC) and the International Development Research Centre (IDRC).

The research focused on farming systems, agricultural productivity, water management and access, and equity issues in resource management for middle-mountain watershed areas of the region. It aimed to design future interventions, and to scale up the successes thus far achieved. This publications summarises the lessons learned and recommendations from the project activities in Nepal as follows.

- Erosion studies from Jhikhu and Yarsha Khola watersheds show that **soil erosion from properly farmer managed agricultural land is much less than originally believed. However, erosion increases when the slope is more than 10 degrees.** Most sedimentation originates from areas such as landslips, degraded slopes, roadsides, gullies, and stream banks. Peak runoff is generally observed during intense and high rainfall reaching daily amounts of 100 mm or more.
- **Nutrient leaching is a far more important issue to farmers than farm soil erosion.** In rainfed agricultural land, the leaching volume at 45 cm depth in the soil profile is significantly higher than surface runoff.
- **Increasing demand for water.** Upland communities are concerned about low flows during the pre- and post-monsoon seasons, which affect both irrigation and household needs. However, the data show that the low-flow problem is not due to reduced precipitation or water supply within the watershed, but mainly to increasing demand for water – both for irrigation and drinking – and to poor local water management.
- **Improving water management.** Some tested technological options include eyebrow pitting in degraded land for improving soil moisture, catchment conservation to improve water availability for drinking water, plastic lined conservation ponds to harvest surface water for irrigation, and harvesting roof-water for drinking purposes. Drip and sprinkler irrigation techniques and the System of Rice Intensification (SRI) are among other options tested for increasing the efficiency of water use.
- PARDYP's research on water quality shows that **microbiological contamination of drinking water is severe** and must be addressed through preventing contamination and improved treatment of both catchments and water sources.
- **Forest area cover** in the Jhikhu Khola watershed **remained stable** between 1972 and 1996. **Forest density improved significantly** during the same period mainly as a result of community forestry programmes that increased people's participation and ownership in the management of forests. The entire community forest area within

the Jhikhu Khola watershed was mapped showing forest types, tree density, and maturity class. These maps helped the District Forest Office Kabhre in planning the community forestry programme in the watershed.

- **Agriculture in the middle-mountain watersheds of the Himalayan region is intensifying and becoming more market oriented**, especially in areas with irrigation facilities and links to markets. However, in order to sustain higher production levels, farmers are applying very high doses of pesticides and chemical fertilisers, which has a negative impact on ecosystems.
- **Black plastic composting** with the use of effective micro-organisms has enhanced the decomposition process and produced better fertiliser to address soil-nutrient needs.
- The **challenge in the middle mountain watersheds is to increase the income of smallholder farmers**, especially those cultivating rainfed land. Low levels of production and small landholdings are pushing young farmers to migrate to urban/semi-urban areas.
- **Issues of poor access, equity, and governance are still of concern and need proper attention**. The workload for mountain women remains higher than for men throughout the year, especially in fetching water, collecting fodder and fuelwood, and household work. In the Jhikhu Khola watershed, women typically work 3.8 hours longer per day than men, and 68% of water fetching is done by women. Roofwater harvesting saved women up to 27 minutes on average for each trip to fetch water in the Jhikhu Khola watershed. Similarly, fodder development on their private land can save women 60 to 90 minutes per day for fodder collection.
- **Dissemination and scaling up of the lessons is a major challenge**. Sharing of messages (success and failure stories) among villages through exchange visits, on-site training camps, farmer field schools, national workshops, farmer days, and similar, has been very effective. In addition, participatory action research proved to be effective in testing new technologies together with farmers. This approach strengthened farmers' behaviour to be research oriented in other areas, which is essential for improving livelihoods.

Acronyms and Abbreviations

DAP	diammonium phosphate
DDC	district development committee
DSCWM	Department of Soil Conservation and Watershed Management
EC	electrical conductivity
EEC	European Economic Commission
EM	effective microorganisms
GOs	government offices
ICIMOD	International Centre for Integrated Mountain Development
IDRC	International Development Research Centre
NGO	non-government organisation
NRs	Nepalese rupees
NTU	nephelometric turbidity unit
PARDYP	People and Resource Dynamics Project
RWSSSP	Rural Water Supply and Sanitation Support Programme
SCDC	Spice Crop Development Centre
SDC	Swiss Agency for Development and Cooperation
SODIS	solar water disinfection
SRI	System of Rice Intensification
USD	United States dollar
VDC	village development committee

Currency Equivalent
In this report all references to rupees (Rs) are to Nepalese rupees

Currency Unit – Nepalese rupees (NRs)
$1 = NRs 56.75 (as of December 1996)
$1 = NRs 71.40 (as of December 2006)

Notes
(i) The Nepalese calendar year (B.S.) runs from mid April to mid April. Unless otherwise stated, year ranges written in the form 2005/06 denote a single calendar year.
(ii) In this report, $ refers to US dollars.
(iii) In this report, tons (t) refer to metric tons or tonnes (1,000 kg).

1 Introduction

Background

The 'People and Resource Dynamics Project' (PARDYP) in mountain watersheds of the Hindu Kush-Himalayas started in October 1996 and continued through three phases to June 2006. It evolved from two projects funded by the International Development Research Centre (IDRC): the 'Mountain Resource Management Project' (in collaboration with the University of British Columbia) and the 'Rehabilitation of Degraded Lands in Mountain Ecosystems Project'. PARDYP was a long-term regional interdisciplinary research programme for watershed development concerned primarily with natural resource dynamics and degradation processes and their effects on livelihoods. The project covered four countries – China, India, Nepal, and Pakistan – with five watersheds: two in Nepal (Jhikhu Khola and Yarsha Khola), and one each in India (Bheta Gad Garur Ganga), Pakistan (Hilkot-Sharkul), and China (Xi Zhuang) (Figure 1). Activities in the Yarsha Khola were discontinued in June 2001 as a result of security problems. ICIMOD was able to broaden PARDYP's partnership and funding support to include not only IDRC but also the Swiss Agency for Development and Cooperation (SDC). The strategic inputs and support of the University of British Columbia continued, and were joined by the University of Berne and the University of Zurich.

The first phase of PARDYP (October 1996 to September 1999) was devoted to establishing research infrastructure, human resources, and systems (Figure 2). In Phase 1 the natural resources research dimensions received more emphasis than social, institutional, or economic issues. The second phase of PARDYP (October 1999 to December 2002) was designed to enhance the community-based approach and to target poverty reduction and improved management of natural resources. The project focused on the development and use of participatory, community-based decision-making processes and developing relevant methodologies. During the third phase of PARDYP (January 2003 to June 2006), the focus was on research for development, with a better balance between natural resources, socioeconomic, and institutional components. An external review portrayed the three phases of PARDYP as an evolutionary process from establishment (set up/data collection), through implementation (data collection/ analysis), to consolidation (analysis/formulating of options).

Sharing of ideas, successes and failures, and research methods by PARDYP partners from all the participating countries contributed significantly to the success of PARDYP research at the country level. Following completion of the project, we are following a number of pathways to disseminate the learning more widely with the aim of contributing to the development of more effective watershed management approaches in other

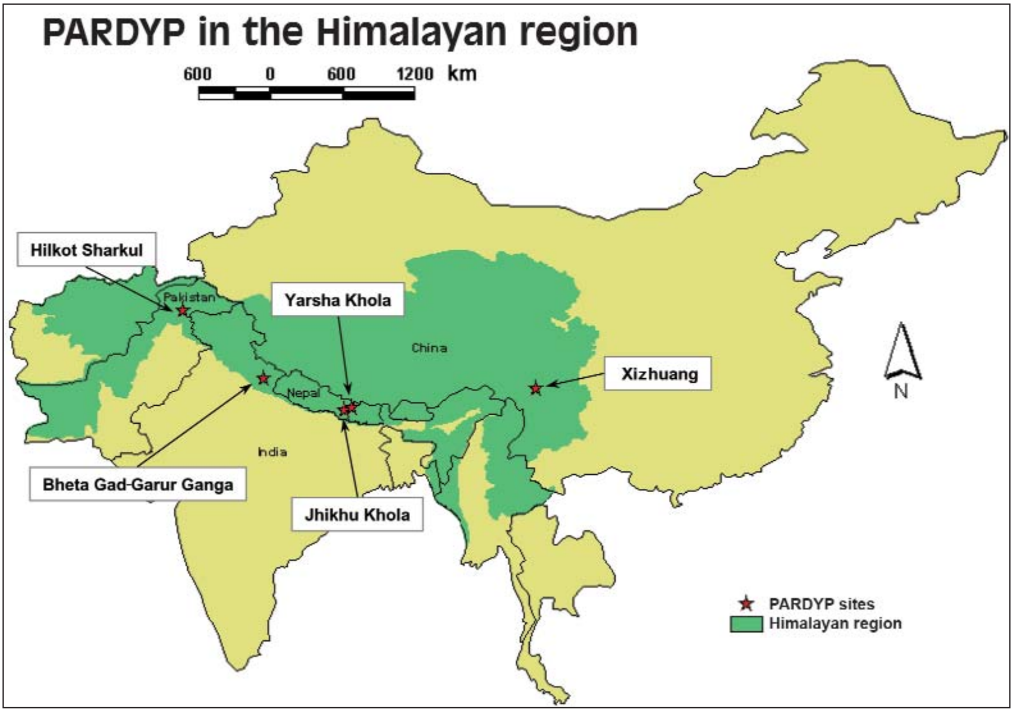


Figure 1: Location of PARDYP watersheds

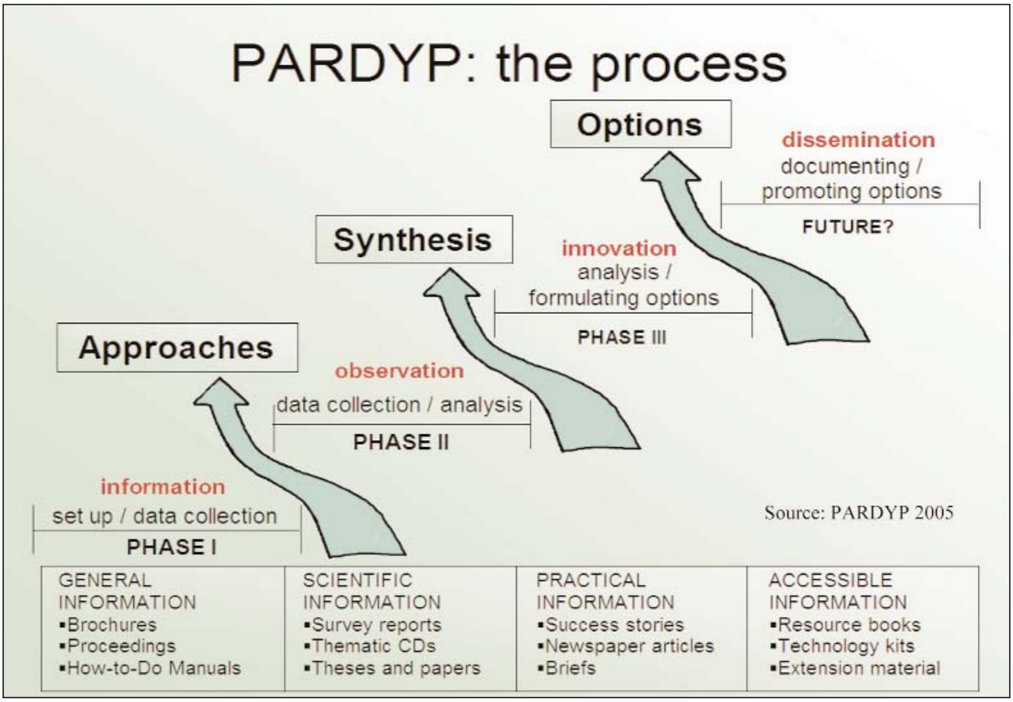


Figure 2: PARDYP history: the three phases with their key characteristics and main outputs related to natural resources (socioeconomic and institutional components not included) Source: PARDYP Phase 3: External Review Report

watersheds in the Himalayan region. The present document is one of these pathways. In it, we summarise the learning from the two watersheds in Nepal during the lifetime of the project in order to share the knowledge with others, as well as to provide a record of the achievements.

Brief Description of the Watersheds

The major characteristics of the Jhikhu Khola and Yarsha Khola watersheds are summarised briefly in the Table 1 and described in more detail in the following. Much of the data is taken from the Livelihood Survey carried out under the project in 2004/05 and prepared as an internal report in 2005 (see box).

Livelihood Survey of 2005

PARDYP conducted a livelihood survey in the Jhikhu Khola watershed to develop livelihood profiles, promote insights into problems and opportunities, and develop linkages with institutions for a comparative study. The fieldwork was conducted between November 2004 and January 2005 using local enumerators. A total of 169 households were selected using spatially stratified random sampling to represent the whole watershed area proportionately. The survey included respondents from Brahmin (37%), Tamang (21%), Chhetri (15%), and disadvantaged groups (17%), the remaining 10% being classified as 'other', with 66% males and 34% females. The results of the study were used in the assessment of PARDYP activities as described in this volume. The report itself is included in PARDYP project documentation which is held in the ICIMOD library for reference.

Table 1: **Major characteristics of the Jhikhu Khola and Yarsha Khola watersheds**

	Jhikhu Khola	Yarsha Khola
Location District Distance from Kathmandu	 Kavrepalanchowk 45 km east of Kathmandu	 Dolkha 190 km east of Kathmandu
Total area (ha)	11,141	5,338
Elevation range (masl)	750 – 2,050	990 – 3,030
Climate	Humid subtropical to warm temperate	Humid subtropical to warm temperate
Dominant geology	Mica schist and limestone	Gneiss and slate + graphitic schist
Topography	High vertical relief, steep slopes, and shallow soils	Steep slopes, no flat areas
Population	48,728 (1996)	20,620 (1996)
Population density 1996 (persons per sq.km)	580	386
Average family size	6	5
Dominant ethnicity	Brahmin, Tamang, Chettri, Danuwar	Tamang, Brahmin, Chettri
Main staple foods	Rice, maize, wheat, potatoes, millet	Rice, maize, wheat, potatoes, millet
Major cash crops	Potatoes, tomatoes, rice, fruit, vegetables	Seed potatoes, fruit

Jhikhu Khola Watershed

The Jhikhu Khola watershed lies in Kabhrepalanchowk District in the central mid hill region of Nepal about 45 km east of Kathmandu (Table 1). It covers an area of 11,141 ha. The watershed lies in the humid sub-tropical agro-ecological zone (Figure 3) with a distinct dry period from November to January and a very wet monsoon from June to September characterised by high-intensity long-duration rainfall. Rainfall information is given in Annex 1. The elevation ranges from 750 to 2,050 masl and is characterised by high vertical relief, steep slopes, and shallow soils (Figure 4).

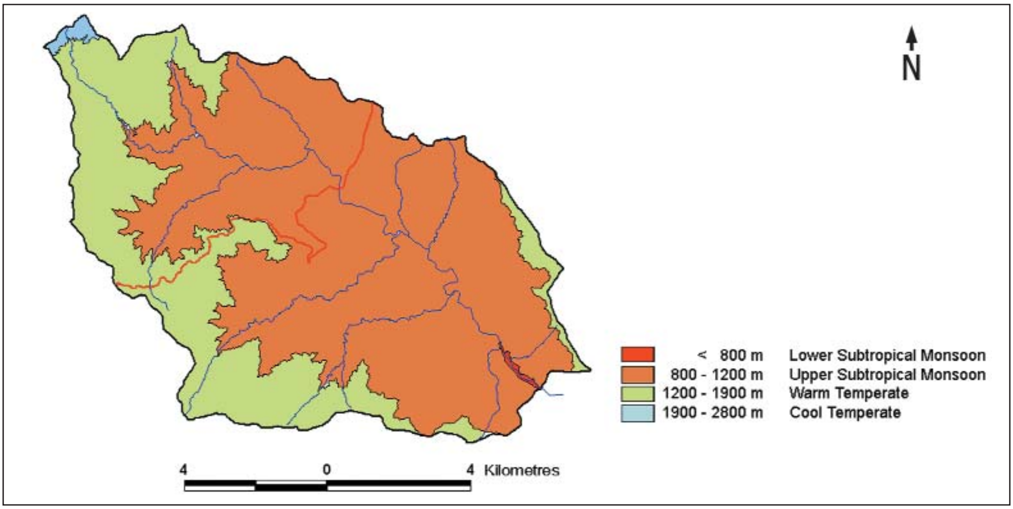


Figure 3: Climate Map of the Jhikhu Khola watershed

Figure 4: View across the Jhikhu Khola watershed

The watershed is among the most densely populated areas in the Himalayas with a projected population density in 2006 of more than 716 persons per km^2 (Table 2). The population growth rate between 1990 and 2001 (around 6% per annum) was much higher than the value across the whole district (1.74% per annum from 1991-2001). The population comprises Brahmins (37%), Tamangs (21%), Chhetris (15%), disadvantaged groups (17%), and others (10%) (Livelihood Survey 2005).

Table 2: **Jhikhu Khola population**

Year	Population[a]	Population Density per km^2	Annual Growth Rate %	Annual Growth Rate %
1947	8,761	79		
1990	31,202	280	3	6% between 1990 and 2001
1996	44,011	395	5.9	
2001	59,242	532	6.12	
2006	79,744[b]	716[b]		

Note: [a]Shrestha 2005a; [b]Projected population based on 1996 to 2001 growth rate

In 2004 the average family size per household was 6.5, with a range from 2 to 19. Some 40% of households had 7 or more individuals, and 20% had 4 members or less. The overall literacy rate was 65-79% for men and 53% for women (Livelihood Survey 2005).

The great majority (77%) of people work in agriculture; 7% (mostly women and older men) are engaged mainly in domestic work, 2% have small shops, and 14% have other services or businesses (Livelihood Survey 2005).

Most people (98%) own their own house, nearly one fifth of households have more than one house. Electricity, including solar, was available in 77% of households questioned, compared with a national average of only 5% (Livelihood Survey 2005). The electricity is mainly used for lighting.

Agricultural land accounts for 55% of total land; forest, grassland, and shrubland for 42%; and other land uses for 3% (Table 3 and Figure 5). Some 96% of households have access to some cultivated land with a median landholding per household of 0.56 ha, including 0.36 ha irrigated land (khet) and 0.15 ha rainfed outward sloping agricultural land (bari). Some 16% of households have less than 0.25 ha of land and 5% more than 2.0 ha (Table 4). Of the total cultivated land, 35% is irrigated, 58% is rainfed, and 7% is steep (pakho and khar bari/waste-land). Around three-quarters of households have access to irrigated land (Livelihood Survey 2005).

The Jhikhu Khola watershed is economically very active in terms of agriculture as a result of its closeness to Kathmandu and to district markets such as Dhulikhel and Banepa.

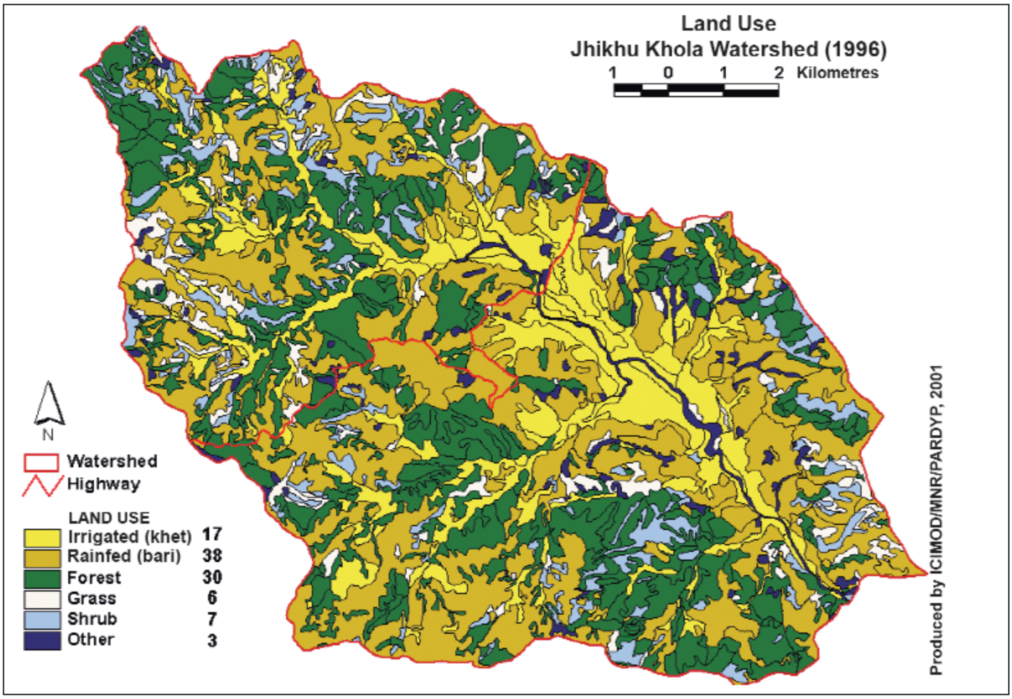


Figure 5: Land use map of the Jhikhu Khola. Source: Shrestha (2005b) based on LRMP (1986)

Table 3: **Land use characteristics of the Jhikhu Khola (1996)**

Land use	%
Irrigated land	16.7
Rainfed land	38.3
Forest	31.2
Grassland	6.8
Shrubland	3.9
Other (%)	3.0
Total Area	**11,141 ha**

Source: Shrestha 2005b, based on LRMP 1986

Table 4: **Cultivated landholdings in the Jhikhu Khola**

Landholding Size (ha)	% of Households
0	4
0.01-0.25	16
0.25-0.50	20
0.5-1.0	30
1.0-2.0	25
>2.0	5

Source: Livelihood Survey 2005

Yarsha Khola Watershed

The Yarsha Khola watershed is located in the central mid hill region of Nepal about 190 km east of Kathmandu on the Lamosangu-Jiri Road in Dolakha District (Table 1) covering an area of 5,338 ha. It lies in the humid sub-tropical agro-ecological zone (Figure 6) with a distinct dry period from November to January and very wet monsoon from June to September characterised by high-intensity, long-duration rainfall. Rainfall information is given in Annex 2. The elevation range is 990 to 3,030 masl. The topography is dominated by steep slopes, with almost no flat areas (Figure 7). The projected population density of the Yarsha Khola watershed in 2006 was about 590 persons per sq.km (Table 5). The population growth rate between 1990 and 2001 of around 4% per annum was higher than the value across the district as a whole (1.65%). The three main ethnic

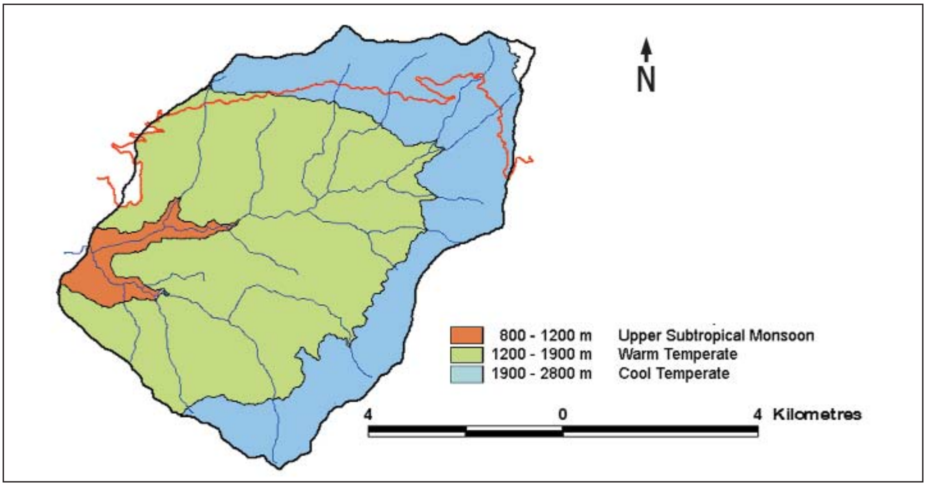


Figure 6: Climatic Map of the Yarsha Khola watershed


Figure 7: View across the Yarsha Khola watershed

communities are Tamang (27%), Brahmin (25%), and Chhetri (25%) (Shrestha 1999). In general, Sherpas and Tamangs dominate the higher parts of the watershed. In 1999, the literacy rate was 70% for men but only 8% for women (Brown 1999).

Agricultural land accounts for 51% of total land; forest, grassland, and shrubland for 43%; and other land use for 6% (Table 6 and Figure 8). Of the total cultivated land, 27% is irrigated and 73% is rainfed. All households have access to some cultivated land with a median landholding per household of 0.8 ha, of which 0.3 ha is irrigated and 0.3 ha is rainfed (Brown 1999). Some 30% of households have less than 0.5 ha of land and 11% more than 2.0 ha (Table 7). The Yarsha Khola watershed is economically less active than the Jhikhu Khola watershed in terms of agriculture as a result of the lack of markets within a reasonable distance.

Table 5: Yarsha Khola population

Year	Population[a]	Population Density per km^2	Annual Growth Rate %
1971	10,885	204	
1981	13,737	257	2.35
1991	16,688	313	1.97
1996	20,620	386	4.32
2006	31,482[b]	590 [b]	4.32

Note: [a] Shrestha 1999; [b] Projected population based on 1991 to 1996 growth rate

Table 6: Land use characteristics of the Yarsha Khola (1996)

Land use	%
Irrigated Land	13.9
Rainfed Land	37.4
Forest	31.5
Grassland	5.8
Shrubland	5.4
Other	6.4
Total Area	**5,338 ha**

Source: Shrestha 1999

Table 7: Cultivated landholdings in the Yarsha Khola

Land Size (ha)	Total land %
<0.5	30
0.5-1.0	38
1.0-2.0	21
>2	11

Source: Brown 1999

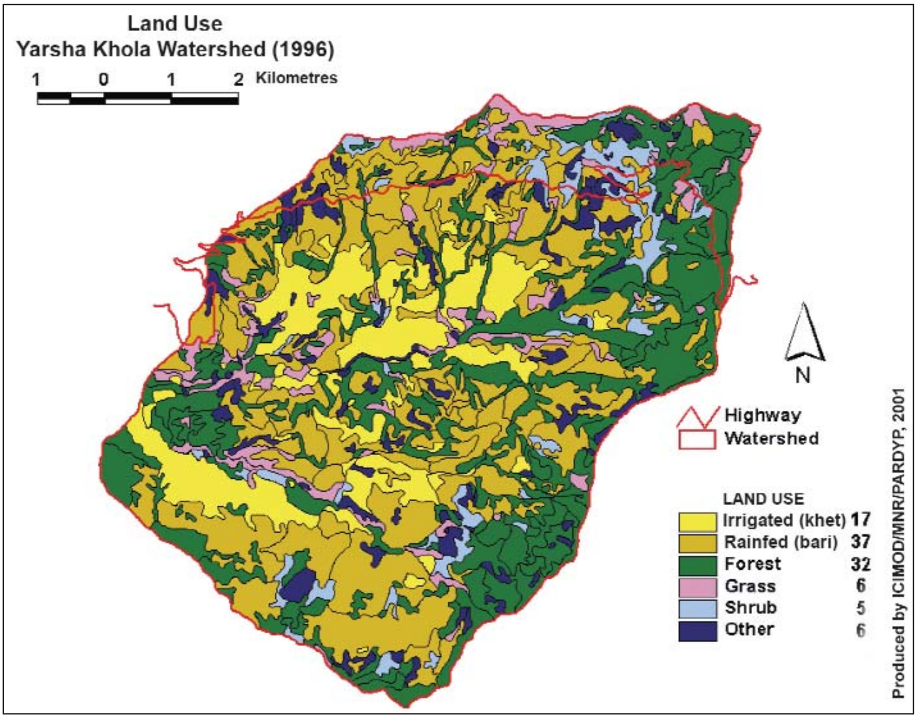


Figure 8: Land use map of Yarsha Khola. Source: Shrestha unpublished data, based on LRMP (1986)

2 Soil loss and runoff

Background

One of the underlying assumptions behind the PARDYP research was that soil erosion is a major problem, leading to environmental degradation, lower yield, and ultimately increasing the poverty of mountain farmers. This is a plausible scenario and fits well with reports of deforestation and soil erosion in the Himalayas. However, the question of whether there is a soil erosion problem, especially on rainfed agricultural land in the middle mountains of the Himalayan region, demands critical review. PARDYP's studies indicate that the amount of soil erosion from agricultural land is much less than generally perceived; the greater part of transported sediment comes from stream and riverbank cuttings, landslips, and erosion from increased runoff associated with roads, footpaths, and settlements. It appears that the soil conservation measures adopted by farmers are effective in reducing soil erosion.

Several studies have shown that significant erosion is taking place in the Himalayan region and that these mountains are a huge source of sediment. In 1976, E.P. Eckholm concluded in his book *Losing Ground, Environmental Stress and World Food Prospectus* that "There is no better place to begin an examination of deteriorating mountain environments than Nepal". Some sediment observations are described in the following.

- The annual sediment measured at Tribeni in the Tamur, Sunkoshi, and Arun rivers were equivalent to losses of 61, 27, and 12 m^3/ha in the watershed areas, respectively (after Gupta 1975).
- The Koshi River in Bihar shifted over 110 km from east to west between 1731 and 1963, destroying about 7,800 sq.km of land in Bihar, India (Gole and Chitale 1966), and 1,300 sq.km in Nepal with sand deposits, wiping out towns and villages, and displacing 6.5 million people (Rieger 1976).
- Satellite imagery reveals that a 40,000 sq.km island is forming in the Bay of Bengal from the silt transferred by Himalayan rivers (Sterling 1976), of which Nepal is the major contributor. The riverbeds are estimated to be rising by 10 to 30 cm per year from silt being deposited (HMGN 1975).
- A sedimentation survey of the Kulekhani Reservoir indicated that the average sediment contribution between the time it was dammed in 1982 to March 1993 was equivalent to a loss of 42 m^3 per ha per yr across the 125 sq.km watershed. During the disastrous 1993 monsoon, this rate increased to 415 m^3 per ha (Sthapit 1996).

The various studies indicate that the major sources of sediment are gully erosion, landslides, stream bank cutting, and sediment-laden flow (Figure 9). The PARDYP study sought to find out which part of the watershed and what land uses are the major sediment contributors and where and when the major erosion processes occur. PARDYP-Nepal set up plots in the Jhikhu and Yarsha watersheds to monitor and analyse differences in runoff and erosion from rainfed agricultural land and degraded land. The plots are described in Annex 3 and detailed results are given in Annexes 4 and 5 and summarised briefly below.

Figure 9: Major sources of sediment

Soil Loss and Runoff Monitoring

Average annual soil loss and runoff

Jhikhu Khola

The soil loss and runoff studies were carried out on two different land use types – rainfed outward sloping agricultural land (bari) and degraded land. The latter was further divided into degraded shrub and degraded treated land. The soil type in five plots was red soil and in two plots non-red soil. The erosion plots were located at the same altitudinal range of about 1,200 m and at sites with similar annual rainfall of about 1,200 mm; therefore differences caused by altitude and rainfall were not significant. Typical plots are shown in Figure 10, and analysis procedures in Figure 11.

The average annual soil loss from rainfed outward sloping agricultural land ranged from 1.3 t/ha (Gharti Thok, non-red soil) to 20.2 t/ha (Higher Chiuribot, non-red soil) (Annex 4, Table 1). The annual runoff from the same plots ranged from 330 m^3/ha to 1,197 m^3/ha (Annex 4, Table 2), about 3 to 9% of the annual rainfall.

Figure 10: Soil loss and runoff plots

Figure 11: Sediment and runoff sample analysis

The natural slope of the agricultural land has been modified to varying degrees by terracing. The slope of the terraces depends on the height of the risers and the natural slope of the terrain. In the plots, the amount of soil loss depended strongly on the slope of the cultivated terrace. Annual soil loss from a rainfed outward sloping agricultural plot with terrace slope 3º to 8º (Bhetwal Thok and Gharti Thok) ranged from 1.25 t/ha to 1.5 t/ha (Table 8, and Annex 4, Table 1), but losses from land with a terrace slope of 15° to 18º (Bela) and 22º (Chiuribot) were as high as 11.38 t/ha and 20.22 t/ha, respectively. The annual runoff from the land with terrace slope 15º to 18º remained close to 3% of the annual rainfall, but increased to 9% of annual rainfall when the terrace slope increased to 22º (Annex 4, Table 2).

Soil erosion and runoff increase significantly on steeper slopes and demand intensive conservation measures such as levelling of the cultivated slope, stable riser construction (stone), and surface runoff management, without which such slopes should not be cultivated.

Table 8: **Soil loss from rainfed agricultural land**				
Description	**Site Code and Name**			
	16A Bhetwal Thok	**17A Gharti Thok**	**6A Bela**	**20A Higher Chiuribot**
Ground slope in degrees	6.7	9.2	20.4	24.5
Terrace slope in degrees	3 and 8	8	15 to 18	22
Average annual soil loss, t/ha	1.5	1.25	11.38	20.22

The annual surface erosion rate in plots of untreated degraded land with red soil and slopes of 15º and 11.5º was 17.6 t/ha and 22.2 t/ha, respectively. One degraded plot with red soil and a 16º slope was treated by planting three double rows of broom grass 5m apart, each row containing two lines of plants 20 cm apart, with individual plants planted 10 cm apart. The annual surface erosion rate in this treated plot was only about 7.7 t/ha (Annex 4, Table 1).

The average annual runoff from the untreated degraded land (100m^2 plot) ranged from 4,100 to 5,300 m^3, 32 to 42% of the total rainfall. Average runoff from the treated degraded plot was only 3,200 m^3, 25% of the total rainfall (Annex 4, Table 2). It seems likely that the lines of broom grass helped to increase infiltration and reduce the surface runoff.

Yarsha Khola

The soil loss and runoff studies were carried out on two different land use types – rainfed outward sloping agricultural land and grassland. The latter was further divided into fallow grassland and grassland with shrubs. Two plots (one each of each type) had red soil and two plots non-red soil.

The average annual soil loss from rainfed outward sloping agricultural land was about 9 t/ha at Jyamire, with non-red soil, and about 16 t/ha at Namdu with red soil, even though the average annual rainfall was higher at Jyamire (2,505 mm; Annex 5, Table 4) than at Namdu (1,676 mm; Annex 5, Table 5). The annual runoff was 3,910 m^3 at Jyamire and 1,889 m^3 at Namdu, 16% and 12% of the annual rainfall, respectively (Annex 5, Table 2). The natural slope of both plots was about 17°, but Jyamire is located at 1,950m with a higher annual rainfall, and Namdu is located at 1,410m with a lower annual rainfall. The plot at Jyamire was moister than the plot at Namdu as a result of the higher elevation, lower soil temperature, and higher rainfall, and generated more runoff.

The average annual soil loss from the grassland with shrubs at Thulachaur (2,300 masl with non-red soil and 19° slope) was only 0.34 t/ha compared to 1.29 t/ha from the fallow grassland at Namdu (1,410 masl with red soil and 17.5° slope) (Annex 5, Table 1). The low rate of soil loss at Thulachaur might be due to the presence of shrubs and non-red soil, but could also be the result of lower temperature, higher soil moisture, more rainfall, and less human interference at the higher altitude. The annual runoff from the same plots was 5,870 m^3 at Thulachaur and 3652 m^3 at Namdu, 21% and 23% of annual rainfall respectively. Namdu had significantly less rainfall than Thulachaur (1,585 and 2,768 mm respectively, see Annex 5, Table 2).

Seasonal variation and maximum events

There were marked seasonal variations in soil loss and runoff, which are highest during the monsoon, followed by the pre-monsoon, and then the post-monsoon. Soil loss and runoff were insignificant during winter in all land use types.

Jhikhu Khola

Soil loss during the pre-monsoon period (March-May) was significant even though only about 15% of annual rainfall occurs in this period. About 44 % of the annual soil loss from degraded land, 26% from degraded shrubland, 8% from treated degraded land, and 32 to 68% from rainfed outward sloping agricultural land occurred during the pre-monsoon period (Annex 4, Table 7).

More than 75% of annual rainfall occurs during the monsoon (June-September); the annual soil loss during this period was 54% from degraded land, 72% from degraded shrubland, 91% from treated degraded land, and 31 to 68% from rainfed outward sloping agricultural land (Annex 4, Table 7). Soil loss during the post-monsoon and winter periods was insignificant.

The highest soil loss events observed in each of the plot types were during the pre-monsoon period (Annex 4, Table 8). The highest event in untreated degraded land was 9.66 t/ha on 8 May 1998, when 10 minute (I10), 30 minute (I30), and 60 minute (I60) rainfall intensities were 100, 44.3, and 23.2 mm/hr, respectively, and in the treated degraded plot was 10.05 t/ha on 10 June 1999, when I10, I30, and I60 were 65.7, 37.8, and 20.9 mm/h, respectively. The highest soil loss event observed in rainfed outward sloping agricultural land was 25.96 t/ha on 28 May 1993, during a cloudburst. This runoff plot was only established in 1993, and the high value of soil loss might have been caused by excessive soil work. The highest soil loss events observed during the monsoon were 8.34 t/ha on 10 June 1999 from degraded land, when I10, I30, and I60 rainfall intensities were 93, 36, and 23 mm/hr, respectively; and 11.95 t/ha on 27 June 1996 from rainfed outward sloping agricultural land, when I10, I30, and I60 rainfall intensities were 76, 42, and 33 mm/h, respectively (Annex 4, Table 9).

Seasonal runoff correlated well with seasonal rainfall in rainfed outward sloping agricultural land — annual runoff during the monsoon period from 70 to 82% compared to rainfall proportion of 78% — and for the degraded shrubland at Baghkhor — annual runoff during the monsoon period 77%, compared to rainfall proportion of 80% (Annex 4, Table 7). However, the proportion of runoff during the monsoon from the untreated degraded land at Kubinde was higher than the proportion of rainfall — 85% compared to 71%.

The highest runoff events occurred during the monsoon (5 plots) or pre-monsoon (2 plots) (Annex 4, Table 10). The highest runoffs were generally the outcome of intense and high rainfall. The highest daily runoffs recorded were all from degraded land (shrub, treated, and untreated) and above 500 m^3/ha, with daily rainfall of were 140 mm or higher. One day with similarly high rainfall in the rainfed agricultural land plot led to a similarly high runoff of 457 m^3/ha. Land use did have an effect on runoff, but when rainfall exceeds the absorptive capacity of the soil there will always be excess runoff. High runoff can contribute to flooding.

Yarsha Khola

Soil loss during the pre-monsoon period (March-May) was also significant in the sites in the Yarsha Khola watershed, 19 to 24% of annual soil loss from grassland and 25 to 53% from rainfed outward sloping agricultural land compared with only 15% of annual rainfall. The proportion of soil loss during the monsoon period — with 75% of the annual rainfall — was 75 to 80% of the annual total for grassland and 47 to 75% for rainfed outward sloping agricultural land (Annex 5, Table 6).

The highest soil loss event observed in grassland was during the monsoon: 0.56 t/ha on 11 July 1998, when I10, I30, and I60 were 74.4, 43.2, and 29.2 mm/hr, respectively (Annex 5, Table 7). The highest soil loss event observed in rainfed outward sloping agriculture was during the pre-monsoon: 5.23 t/ha on 25 May 1999, when I10, I30, and I60 were 34.8, 24, and 22.2 mm/h, respectively. The highest soil loss event observed in rainfed outward sloping agricultural land during the monsoon was 2.54 t/ha on 18 July 1997 (Annex 5, Table 8).

Overall, the percentage of runoff during the monsoon in grassland and rainfed outward sloping agricultural land was slightly higher than the percentage of annual rainfall; whereas the percentage of runoff during the pre-monsoon, post-monsoon, and winter seasons was lower (Annex 5, Table 6).

All the highest runoff events per plot occurred during the monsoon, with a maximum of 432 m^3/ha in grassland and 513 m^3/ha in rainfed outward sloping agricultural land, following a total daily rainfall of 119 and 98 mm, respectively (Annex 5, Table 9).

Discussion

Although soil loss from the rainfed outward sloping agricultural land with a terrace slope of more than 15° and from degraded land was significant, the greater part of soil loss actually appears to come from non-agricultural land. Sthapit (1996) showed that the high rate of sediment contribution from the watershed to the Kulekhani reservoir under the extreme rainfall conditions in 1993 (377 mm in Simlang, 419 mm in Sarbang, and 535 mm in Tistung over a 24-hour period with intensities of 67 and 70 mm/h in Simlang and Tistung, respectively) was mainly from slope failures and stream-bank cutting, rather than from surface erosion from agricultural land.

In general, the quantity of soil loss from surface erosion of agricultural land is less than soil loss from degraded land. However, the value of the soil lost from agricultural land is higher because agricultural land gives higher economic returns than degraded land.

Therefore, conservation measures on agricultural land must be given high priority. Effective conservation measures include improved farmland water management, grass planting on risers, hedgerow planting, terracing, and multiple cropping.

In rainfed outward sloping agricultural land, the coincidence of intense rainfall with soil preparation for planting crops results in high soil loss events. The highest soil loss event observed in rainfed agricultural land was 25.96 t/ha in the Jhikhu Khola during the pre-monsoon period on 28 May 1993, and resulted from land preparation for a new May crop. The ground cover was almost nil and the rainfall intensity high. This is a primary reason for the high erosion rate during the pre-monsoon in rainfed outward sloping agricultural land. Although the exceptionally high value of soil loss in the Jhikhu Khola plot was partly due to soil work for plot construction, the second-highest soil loss event in rainfed agricultural land was from a plot that had been established for six years: 17.2 t/ha at Chiuribot on 22 June 2004. This loss also occurred during the early monsoon when ground cover was low.

Designing cropping patterns to maintain some cover crop during the pre-monsoon, along with conservation measures such as multiple cropping, mulching, and conservation tillage, could help reduce loss of fertile topsoil during the pre-monsoon period. Managing water for growing cover crops during the dry period would be the first step for addressing this issue.

High-intensity rainfall and lack of ground cover also resulted in high soil loss events in degraded land in both the pre-monsoon and monsoon periods.

Farmer's Perceptions

In the 'Water Demand and Supply Survey' carried out in 1998 in the Yarsha Khola and in 1999 in the Jhikhu Khola, PARDYP asked farmers about major water related issues (Merz et al. 2002). Farmers in both watersheds considered water quantity for irrigation to be the most important issue followed by water quantity for drinking. Only a few respondents considered flooding, surface erosion, or slumping, respectively, to be the major water related issue (see Chapter 3).

If separate questions had been asked on erosion issues (landslide, slumping, gully erosion, riser failure, surface erosion, and flooding) rather than mixing the issue with water availability and quality, the responses might have been different. The perception of farmers depends on the information and knowledge they have. If the farmers had been aware that most of their total manure inputs are washed away in the first few rains, their perception towards erosion issues might have changed. Furthermore, if people don't have solutions to their problems, they may not perceive them as problems but rather consider them as simply part of life. Therefore, farmers might not have perceived surface erosion as a problem.

Farm Management

Stream bank erosion, gullying, road slope erosion, riser failure,and slumping are actually major soil erosion problems. Stream bank erosion, however, only affects a small number of farmers who own land along rivers. Gullying is often observed along trails and on severely degraded, often community-owned land. Stream bank erosion and gullying require external support for treatment. Treating road slope erosion is generally beyond the scope of the community and is best left to the concerned agencies. Generally farmers repair small riser failures that affect a few terraces in bari and khet lands. Larger-scale slope failures affecting dozens of terraces can take several years to repair. Slope failure on agricultural land is normally managed by farmers within a fairly short time, reducing the sediment yield and overland flow.

Erosion from small irrigation canals is mostly managed and repaired by farmers themselves. Irrigation also returns a significant amount of sediment to agricultural land, and vegetation on risers traps soil from surface runoff. Proper irrigation systems and vegetation on risers can play a significant role in managing sediment within a watershed. Figure 12 shows the typical appearance of managed slopes.

The soil loss from the experimental plots actually shows erosion processes under artificial conditions, because there is no effect from the runoff and sediment flow from up-slope. Due to the plots' galvanised iron boundary plates and narrow width, farming practices, especially ploughing, are carried out differently. Many fields are ploughed by bullocks, but not the plots. Biotic interference (mainly from animals) is less in plots than

Figure 12: Farmers' management of agricultural lands

on farmers' land. Slope failure is thus less likely in the runoff plots than in farmers' fields. On the other hand, soil is significantly more disturbed when establishing runoff plots. Overall, soil loss from runoff plots is generally higher in the initial period and lower in the following years compared to the real situation.

According to Mathema and Singh (2003), erosion plots only provide information on surface soil loss. Simple extrapolation of research results from these small-scale studies to a larger scale can lead to meaningless or even dangerous generalisations, because the processes involved are different at different scales. Misleading or inappropriate conclusions can be drawn when erosion plot data are quoted out of context.

Lessons Learned and Recommendations

Soil loss and runoff monitoring

Annual soil loss

- In general, soil loss is higher from degraded land than from agricultural or pasture land.
- Soil loss from rainfed outward sloping agricultural land increased with increasing slope.
- Soil loss from degraded land can be cut by half with simple conservation treatment (hedgerow planting across the slope).
- In disastrous rainfall conditions (such as cloudbursts), most sediment comes from mass movement such as landslides, riverbank cutting, road slope failure, and riser failures.
- Soil erosion from properly managed agricultural land is significantly lower than from unmanaged agricultural land.

Annual runoff

- Rainfed outward sloping agricultural land generates significantly lower runoff than grassland, which in turn generates lower runoff than degraded land. However, an increase in terrace slope in the rainfed agricultural land increases the runoff significantly.
- Red soil contributes more runoff than non-red soil as a result of the lower infiltration.
- Significant increases in annual rainfall increase runoff.
- Vegetative barriers can reduce runoff significantly by increasing the infiltration rate.

Conservation priorities

- Although in terms of quantity soil loss from agricultural land is less than from degraded land, in economic terms the loss from agricultural land is more significant.
- Agricultural land should be given top priority for conservation of soil and nutrients, but erosion from degraded land may lead to off-site impacts and so cannot be ignored. If degraded lands are common resources, priority must be given to them as well. Once degraded land is rehabilitated, it becomes a vital resource for the poor.

Seasonal variations and maximum events

- The study of seasonal variations in surface erosion processes is very important for designing conservation measures, but the total amount of annual soil loss should also be considered when deciding on investments.
- Cover crop and soil work during land preparation are key factors affecting the amount of surface erosion occurring during intense rain.
- Conservation measures to maintain ground cover during intense rain play an important role in reducing surface erosion. These include maintaining cover crops during the pre-monsoon period, mulching, relay cropping (growing of another crop before clearing the previous one), and multiple cropping.
- Year-round irrigation with full management control is essential so that appropriate crop cover patterns can be designed and implemented.
- Stall feeding with a cut-and-carry system can reduce surface erosion in grassland and pasture; erosion rates are very low in protected grassland runoff plots but are quite high in free-grazing areas.
- The highest runoffs are generally the outcome of intense and high rainfall. Land use does effect runoff, but when rainfall exceeds the absorptive capacity of the soil, excess runoff will cause floods.
- In general, peak runoffs are observed when daily rainfall exceeds 100 mm.

Farmers' perceptions

- It is important to consider farmers' perceptions when managing natural resources. When designing survey questions, it is appropriate to separate questions regarding water availability from those related to erosion.
- Research on nutrient loss due to surface erosion needs to quantify the nutrient loss. Extension services must share information with farmers and encourage farmers to adopt necessary conservation measures.
- Proper conservation of agricultural land is essential for its sustainable use.

Overall

- Soil erosion is a complex process. For better comparison of results, it is recommended to establish erosion plots under similar climatic, soil, geology, and landform conditions, preferably in one place, rather than in different places with different conditions.
- The complex nature of erosion and runoff studies can result in unexplainable data. The probable causes of such unexplained data must be verified and documented to permit appropriate analysis. For example, on some days with high rainfall and runoff there may be no soil loss, whereas on other days in the same week with low rainfall and runoff there may be significant soil loss.
- Systematic documentation of the information and process is essential, especially if there is staff turnover, to permit valid data analysis at the end of a project.
- Standard procedures for measurement must be strictly followed if valid data are to be obtained. Continuous supervision and reflection must be integral to the study and deviations from stated procedures must be documented.

3 WATER SCARCITY

Background

Water is rapidly becoming one of Nepal's major concerns, with too much water during the monsoon and too little during the dry winter months. In rural areas, the increasing population has increased the problem of water shortage. According to the 1998/99 water demand and supply survey carried out by PARDYP (Merz et al. 2002), 33% of respondents in the Jhikhu Khola watershed and 41% in the Yarsha Khola watershed thought that shortage of water for irrigation was the most important water issue; 27% in the Jhikhu Khola and 37% in the Yarsha Khola thought it was shortage of drinking water; and 17% in the Jhikhu Khola and 9% in the Yarsha Khola identified drinking water quality is the major problem (Figures 13, 14).

The survey asked whether respondents thought that the supply of irrigation water (men) or domestic water (women) had changed over the last 5 and 25 years. In the Jhikhu Khola watershed, 38% of respondents thought that there was less water, 29% indicated no change; 24% did not answer, and 9% thought that there was more water. In the Yarsha Khola watershed, 79% of respondents thought that there had been no change in water supply, 17% that there was less water, 2% that there was more water, and 1% did not answer (Merz et. al. 2002). Furthermore, 60% of Jhikhu Khola respondents perceived their area as dry and 14% as very dry.

Overall, the supply of irrigation water is perceived to have decreased over the last 5-25 years, as has the supply of drinking water, if not as dramatically. Drying up of rivers, lack

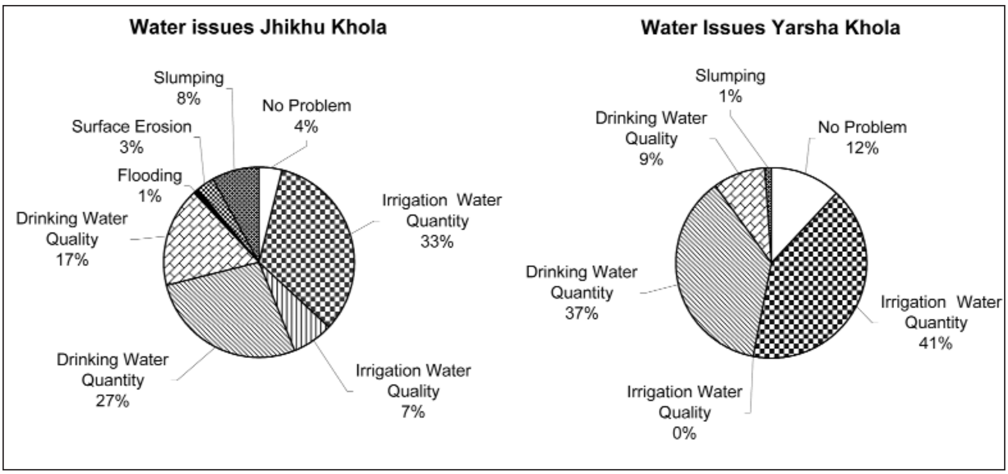


Figure 13: Water-related issues Source: Merz et al. 2002


Figure 14: Water scarcity in the watershed

of water for irrigation, and long queues at the public water sources underline the view that water is a scarce resource.

The question is whether the increasing water scarcity perceived by farmers is the result of increased demand due to increasing population and intensification of agriculture, or of reduced supply due to climate change or others.

Water Demand and Supply

The population in the Jhikhu Khola watershed has been growing faster than the national population (see Table 1), and population density has increased significantly (Figure 15). A growing population leads to increasing water demand for both consumption (drinking) and production (irrigation).

Demand for household consumption

The water demand and supply survey showed that people in the Jhikhu Khola watershed used 23 litres per day per person for domestic purposes, half the guideline of 45 litres per day for rural water supply schemes (RWSSSP 1994). The estimated total water demand almost doubled between 1996 and 2006 (Table 9).

With increasing awareness of sanitation issues, domestic water demand may increase even more in the future. The 2004/05 Jhikhu Khola watershed livelihood survey showed that 46% of the residents use modern toilets, both flush and non-flush types. This number has increased significantly in the last few years.

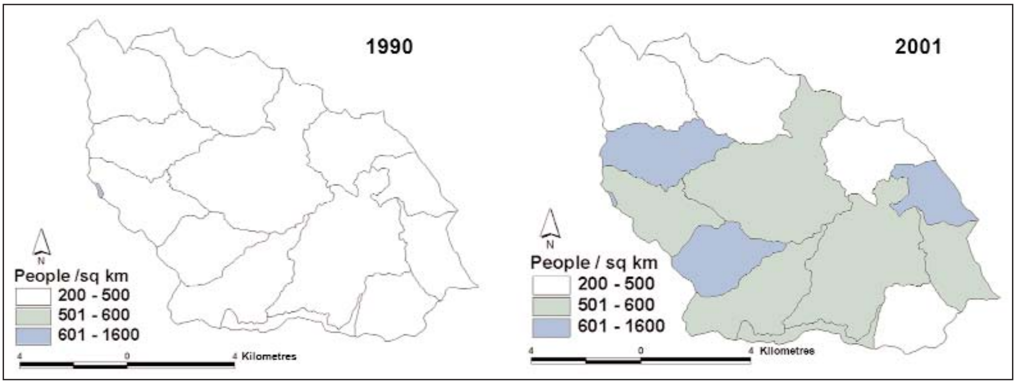


Figure 15: Population density in the Jhikhu Khola watershed

Table 9: **Estimated domestic water demand in the Jhikhu Khola watershed**

	Water demand for household purposes[a]			
	1990	1996	2001	2006 (projected)
Population	31,202	44,011	59,242	79,744
Annual water demand in m^3	261,941	369,472	497,337	669,451

[a] Calculated at 23 litres per person per day

In 1998 people started digging wells, and by 2005 more than 200 dug wells had already been constructed for domestic use.

Demand for agriculture

Agriculture is the main occupation of people in the Jhikhu Khola watershed, with 77% of watershed residents involved. However, the growing population builds pressure through intensification of land use (Figure 16). Over the last 24 years (1972-1996) non-irrigated land (bari) has increased by 4 % and irrigated fields (khet) by 2 %. Most of the suitable land has been converted into paddy, and grassland has decreased by 4%. Most shrubland has been turned into forest land; the former decreased by 12% and the latter increased by about the same amount (Table 10 and Figure 17).

In the 1950s the whole valley bottom of the Jhikhu Khola watershed was only used for growing rice in the monsoon and was left fallow during the rest of the year. During the monsoon, the farmers who lived at higher elevations came down to the valley each day to work their farms and returned home before dark. Farmers in the hills liked to keep the prime agricultural land for cultivation of rice and in many cases did not want to stay in the lowlands because of malaria. Nowadays the situation has changed due to improved medical facilities, eradication of malaria, improved access, and growth of communications and transportation. These improvements have led people to move from the hills to the valley bottom and to shift from subsistence to more commercial farming.

The Jhikhu Khola watershed is characterised by a very high population density and small landholding sizes — 0.56 ha median total landholding and 0.51 ha median agricultural

0: Land use change in the Jhikhu Khola watershed[a]									
Land use types	1947[b]	1972[c]		1981[d]	1990[c]		1996[c]		Difference between 1972 and 1996 (%)
	Area	Area		Area	Area		Area		
	(%)	(ha)	%	(%)	(ha)	%	(ha)	%	
Agriculture total	49	5,497	49	59	6,073	55	6,130	55	+5.7
Irrigated		*1,653*	*15*	*59*	*1,719*	*15*	*1,864*	*17*	*+1.9*
Rainfed		*3,844*	*35*		*4,354*	*39*	*4,266*	*38*	*+3.8*
	50	4,038	37	41	4,296	38	3,913	35	-1.1
Forest	*43*	*2,181*	*20*	*19*	*3,359*	*30*	*3,479*	*31*	*+11.7*
Shrub	*7*	*1,857*	*17*	*22*	*937*	*8*	*434*	*4*	*-12.8*
		1,184	11		466	4	762	7	-3.8
		422	4		306	3	336	3	-0.8

Total area 11,141 ha; [b]Indian Topographical Sheet; [c] PARDYP/ ICIMOD land use maps, scale 1:20,000, using land use mapping and Geographic (GIS); [d]Land Resource Mapping Project (LRMP 1986)

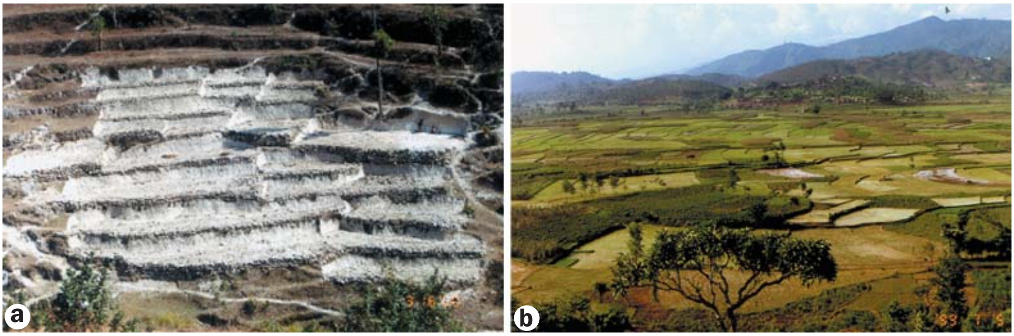


Figure 16: Agricultural intensification a) Conversion of grazing land to agricultural land; b) Cropping intensification in the fertile valley bottom

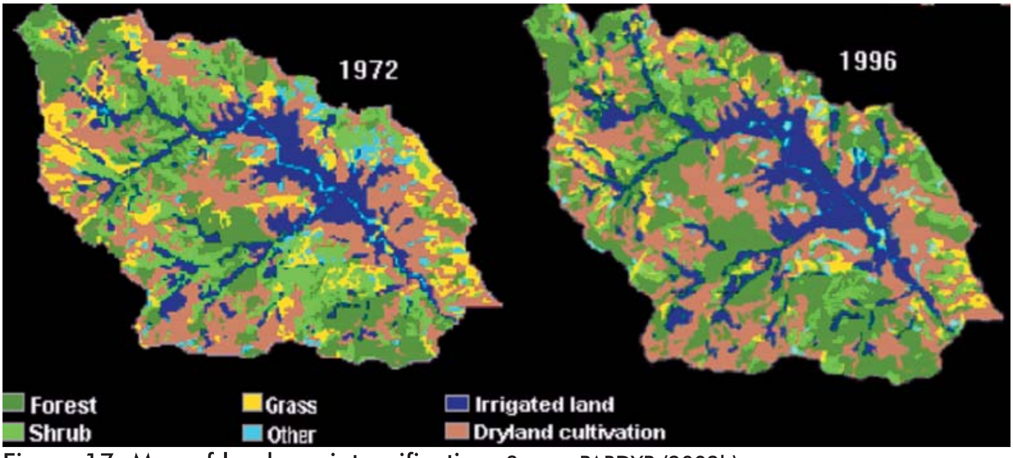


Figure 17: Map of land use intensification. Source PARDYP (2002b)

landholding (Livelihood Survey 2005). Farmers practise commercial farming with high inputs of labour, irrigation, chemical fertilisers, and pesticides with three to four crops grown per year at certain appropriate sites. Cropping intensity on irrigated agricultural land increased from 213% in 1994 (Juerg et al. 1999) to 226% in 2004 (Livelihood Survey 2005). Expansion of agricultural land and agricultural intensification adds to the pressure on water resources.

PARDYP analysed the crop water requirement in the Jhikhu Khola watershed based on the cropping pattern and area under different crops as estimated by the socioeconomic surveys of 1994 and 2004 (Annex 6). The analysis indicated increased demand of about four million cu.m water or 7% between 1994 and 2004 (Table 11). This finding is supported by the findings of the water demand and supply survey. The increased water demand is mainly during the pre-monsoon, and to a lesser extent the post-monsoon seasons and is due to vegetable farming.

Table 11: **Estimated crop water requirement for agricultural consumption in the Jhikhu Khola watershed**

Period	Crop water requirement for agriculture ('000 m^3)		
	1994	2004	Difference
Pre-monsoon (March, April, and May)	3,127	5,531	2,404
Monsoon (June to September)	36,006	36,450	444
Post monsoon (October-November)	7,231	7,762	531
Winter (December to February)	8,208	8,617	408
Total	**54,573**	**58,360**	**3,787**

Water Availability

A water availability study was carried out by analysing monthly, seasonal, and annual rainfall data measurements from the Jhikhu Khola watershed (Figure 18). The average annual precipitation was 1,338 mm; with upper and lower limits of probable annual rainfall of 1,538 mm and 1,138 mm, respectively (95% confidence). The upper limit for rainfall was 232 mm pre-monsoon; 1,141 mm in the monsoon; 102 mm post-monsoon; and 63 mm in winter.

Figure 18: Hydro-meteorological monitoring stations

On average 15% of total annual rainfall falls in the pre-monsoon period, 78% during the monsoon, 5% in the post-monsoon, and 3% in the winter. November to March are dry months; June to September wet; and April, May, and October in between. The probabilities of having no rain in the months of January, February, March, October, November, and December are 13%, 26%, 16%, 22%, 12%, and 24%, respectively (see Annex 7 for detailed analysis).

Management Options

A combination of small household-level technological options together with participatory and community-based approaches were found to be suitable for tackling the water problem. Technological options should be implemented in parallel with socio-cultural and institutional aspects for better management of water resources. The options can be divided broadly into three groups: methods to improve water infiltration into the soil, methods for water harvesting, and approaches for improving the efficiency of water use.

Improved infiltration

Terracing can be used to modify the slope of land from 50% to 5%, which reduces direct runoff and increases infiltration, thus improving soil moisture status and productivity (for a detailed description see Chapter 5).

Moisture stress is the major constraint for vegetation in drier sites. **Eyebrow-pitting** can be an option for harvesting rainwater and improving infiltration, thus improving soil moisture (Figure 19). PARDYP tested the use of eyebrow pits to help rehabilitate degraded dry land in Dhotra in the Jhikhu Khola watershed. The results were very encouraging (see also Chapter 5).

Catchment conservation is another option for improving infiltration. PARDYP supported the renovation and catchment conservation of the Barabot spring, facilitating formation of a user group in the process. Together with this user group, the source was protected using structural measures so that no direct flow of surface water could enter the source, thus reducing contamination. The user group was encouraged and supported to plant grass and tree seedlings in the catchment area of the spring (Figure 20). The flow of the spring was assessed to help design management strategies for the spring and address water scarcity (Figure 21). The results of the catchment conservation were promising; water availability increased and the neighbouring villagers and school began using the source in addition to the permanent users. Microbiological contamination and turbidity decreased (see Annex 8 for details).

The following possible management strategies were suggested.

- Explore other possible water sources to add to the spring tank.
- Protect the catchment area to prevent animal intrusion and maintain vegetation so that water yield during the dry period can be increased.
- Conservation of the catchment area through small vegetative erosion control structures like palisades to increase the infiltration and store the infiltrate water in

Figure 19: Eyebrow pits to improve infiltration on degraded land

Figure 20: Conservation of the spring at Barabot-Dhotra

Figure 21: Flow measurement of the spring at Barabot-Dhotra

the soil mantle — the water thus conserved later seeps into the spring. Selecting the right species for planting in the catchment areas will help keep evapo-transpiration low. Broadleaved species indigenous to the locality are preferable. Species like bamboo, pine, and eucalyptus that have high evapo-transpiration rates should be avoided.

- Close the spring with structural measures to protect it from direct runoff and stop fetching water directly from the spring, which will significantly reduce the water pollution. Instead siphon water from the spring to a collection tank and collect water from the collection tank through taps. Beyond the highest water level limit, the inflow water will be lost through underground seepage. Siphoning the spring water to the collection tank will save such underground seepage loss and help store all water for proper use.
- Set a seasonal limit on the quantity of water that each household can collect per day (total water yield per day in litres divided by number of households). This might vary with dependency on the source. For example, people living nearby depending solely on the Barabot spring might get more than other households that have access to other sources as well. It might also depend on the number of people in a household.
- Charge fees to users for regular maintenance as per the consumption rate or number of people in the household.

Water harvesting

Water availability is a major constraint to multiple cropping on rainfed agricultural land. Traditionally, upland farmers are restricted to a single crop while counterparts in the valley bottom with irrigation facilities grow multiple crops. One possibility for increasing water availability is to store excess runoff water in conservation ponds or use it to recharge groundwater, especially by putting it in a well for use when the crop water requirement is higher than rainfall. PARDYP tested the options of storing excess water in plastic-lined conservation ponds and in underground cisterns (tank) for later use in irrigation, as well as of rooftop rainwater harvesting and improving dug wells.

Traditionally, **conservation ponds** are very popular for storing excess runoff water, thus reducing erosion, to allow water to seep into the ground, and to improve soil moisture down-slope. The stored water is used for purposes such as watering cattle (aahale), raising fish, irrigation, and entertainment. Earthen ponds are simple, cheap, and durable but have high seepage losses that reduce effectiveness. Compacting heavy clay 30 cm deep on the floor of the pond can significantly reduce vertical seepage loss. Similarly, a 30 cm thick layer of heavy clay should be compacted between the wall and the ground to reduce horizontal seepage. Addition of cow-dung and puddling will help seal seepage pores. Watering of buffaloes in such ponds also helps reduce seepage. PARDYP tested lining of ponds with an high density polythene sheet or SILPAULIN (multi-layered, cross laminated, ultravoilet stabilised plastic sheet) to reduce seepage (Figure 22). Conservation ponds can be integrated with drip and sprinkler irrigation systems, and vegetable and fish farming to enhance their economic benefit.

Figure 22: Plastic lined conservation ponds

Surface runoff harvesting can be combined with **storage in underground cisterns** to save evaporation loss. PARDYP built two underground cisterns with local people on a dryland slope at Kubinde (10 m^3 capacity) and Hokse (30 m^3 capacity) as a pilot test (Figure 23). Water collection canals with sediment trapping mechanisms were constructed to drain runoff water to the cistern. Water was siphoned out through a flexible polythene pipe for irrigation. Local materials like stone and sand were collected by farmers, and other materials such as cement and good quality sand were paid by the project. The 10 m^3 cistern cost about US$ 365 and the 30 m^3 cistern cost about US$ 1,000. The farmers with the 30 m^3 cistern initially used it to provide irrigation water for vegetable farming, now it is used to support poultry farming. The 10 m^3 cistern was not much used and was almost abandoned, but in 2005 one farmer used the water collected in the cistern for the rice seedbed when water was unusually scarce. Cisterns are generally evaporation free. Although sediment-trapping mechanisms are provided, runoff water is not completely sediment free, and sediment collected in the tank must be cleaned regularly. Construction of large cisterns is very dangerous and difficult in the hills of Nepal where there are few highly skilled workers. The farmers involved in the construction of the test cisterns do not desire to make another attempt due to the high costs and the inappropriateness of the technology for mountain areas.

Figure 23: Underground water storage system

Roof-water harvesting is slowly becoming popular in Nepal. Different methods are used to collect the water. PARDYP tested roof rainwater harvesting using home-constructed ferro-cement jars for water collection (see Annex 9 for details). Thirteen jars were constructed in the Jhikhu Khola watershed and 9 in the Yarsha Khola watershed (Figure

24). The results showed that the system was appropriate for filling gaps in drinking water supply. The total cost of one jar and gutter system (2,000 litres capacity) ranged from NRs. 6,000 to 8,500 (approx. US$ 85 to $120) depending upon the distance of the construction site from the roadhead and the number of systems constructed in one locality. The PARDYP water demand survey indicated that average daily water use per person is about 23.2 litres, so a 2,000 litre jar can meet the domestic water demand of a family of six for about a fortnight (Annex 9, Table 2). Rainfall analysis at five different sites – Tamaghat, Kalikasthan (Dhulikhel), Bela, Bhetwal Thok, and Acharya Tole – indicated that harvesting water from a roof area of 20 m^2 could fulfil all water needs of a family of 2-4 people from June to September, and 30, 80, and 40% of the total water needs in April, May, and October, respectively (Annex 9, Table 11). The roof area can be increased by adding a plastic sheet to collect water. This is needed where natural water sources are distant or scarce. Doubling the roof area doubles the quantity of water collected, therefore the supply period will also be doubled as long as the jar is sufficiently large. Based on cumulative weekly rainfall and the total monthly runoff harvested, a minimum jar size of 1,000 litres is recommended to collect water for a family of 2-4 and a jar size of 2,000 litres for a family of 5 or more. A jar size of 500 litres may be too small to be useful even for a small family, since the rain is not uniformly distributed in each month.

Groundwater is increasingly used to address the increasing water demand caused by swelling population and intensification of agriculture. In the Jhikhu Khola watershed, the number of **dug wells** increased to more than 200 in 2005 from just a few in 1998. PARDYP monitored the monthly water level in the dug wells from August 2000 to December 2005 to assess the dynamics of the shallow groundwater table (Figure 25). The water table measured from the soil surface at the wellhead showed very different patterns in different wells. In most of the wells a clear seasonal pattern was visible with a recharge period lasting from one to four months, usually around May to August, and a recession period lasting from August to April or May. The water table in the dug wells was higher during the monsoon and gradually decreased during winter, dropping to a minimum during the dry pre-monsoon period (Annex 10). The water levels in the dug wells ranged from a minimum of 2.5m to a maximum of 10.5m. Most of the wells

Figure 24: Roof-water harvesting system

Figure 25: Monitoring the water table in dug wells

showed a decrease in water table with cessation of rainfall. Wells located on the slope close to the top of a continuous ridge (Annex 10, Figure 2) were recharged very fast,usually the maximum water level was reached within one to two months of the onset of the monsoon, however the water table dropped very quickly after rainfall ceased. Wells located near a stream showed only a slight seasonal pattern and very low differences between high water table and low water table. These wells benefit from direct recharge via river flow. Overall the study showed that dug wells can be a good source of drinking water as well as water for irrigation. Wells should be located near streams to get more water yield. Qualitatively, wells must be properly constructed to avoid microbiological contamination and leaching of chemicals.

It is important to understand the **water balance situation** in order to plan water management effectively. PARDYP analysed the water balance in the Jhikhu Khola watershed first dividing the area into two zones, one above and one below 1200m elevation (Annex 11). The overall water balance was in surplus in the upper zone and in deficit in the lower zone (Annex 11, Table 5), but there were deficits from October to March in the upper zone and from October to May in the lower zone (Figure 26). Water availability for irrigated (khet) land was in deficit from October to March and in June in the upper zone, and throughout the year except in July and August in the lower zone. Water was deficit in rainfed (bari) land from November to April in both zones (Annex 11). Overall, the watershed had a surplus of about 5.5 million m^3, about 4% of the total rainfall, but with a seasonal deficit from September to May.

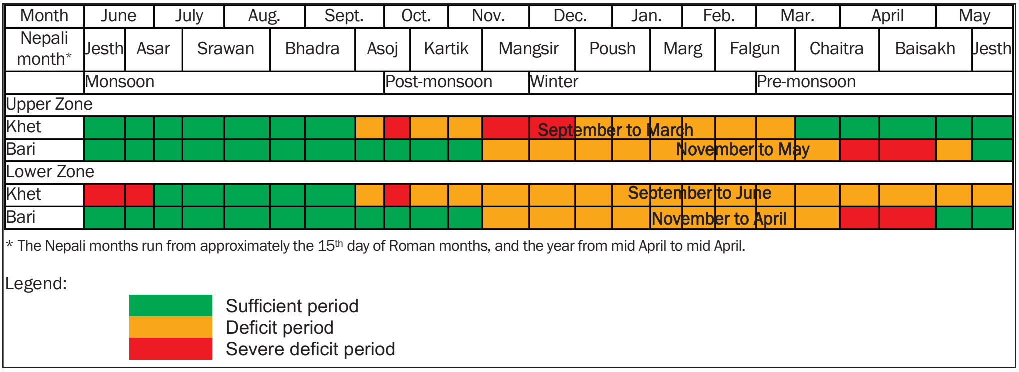


Figure 26: Overall water balance in the Jhikhu Khola Watershed

It is possible to **harvest runoff water in a pond** and use it when needed to fulfil the crop water requirement for small-scale vegetable farming in rainfed outward sloping agricultural lands. Similarly, efficient **management of irrigation canals** is a major option for fulfilling the water demand of irrigated (khet) land. These options not only supply water to the fields but also recycle sediment and nutrients back to the land, reducing sedimentation downstream and increasing soil fertility. The water balance analysis indicated that harvesting runoff is a potential option to fill all additional crop water requirements in September and 65% of requirements in November in the upper zone, but is not very useful for other months. In the lower zone, such harvesting could fill all additional crop water requirements from September to January and 40% of requirements in February. In order to fill the additional water requirement for a hectare of rainfed land, a pond of area 200 m^2 and effective pond height of 1.25m is recommended for the upper zone for the months of September to October and of area 150 m^2 in the lower zone for the months of September to January. The catchment area required for these ponds is about 3 ha in the upper zone and about 2 ha in the lower zone.

A **strategy** must be developed which emphasises and promotes the construction of irrigation canals, runoff harvest ponds, dug wells, conservation ponds, and check dams to address water management in the Jhikhu Khola watershed for commercial cultivation. Efficient water use technologies must also be introduced.

Efficient water use

Water requirements can be reduced by using available water efficiently. PARDYP has demonstrated various options for this.

Drip irrigation – a method of watering plants by delivering drops of water in a controlled way to plant root zones – is an effective way of reducing the water requirement for vegetable farming. In the PARDYP Water Demand and Supply Survey in the Jhikhu Khola watershed, 33% of respondents mentioned irrigation water shortages, particularly during the pre-monsoon season. Farmers in the Jhikhu Khola watershed have been growing high-value cash crops due to the easy access to the Kathmandu market, especially spring vegetables such as bitter gourd, cucumber, cauliflower, and tomato grown during the pre-monsoon period (March to May) when there is a great scarcity of water. Although pre-monsoon rain partially fulfils the crop water requirement, there is an unmet requirement of about 2 million m^3 of water (Table 12). PARDYP tested drip irrigation in the Jhikhu Khola watershed (Figure 27). The system consisted of a water tank and a network of pipes with drippers at predetermined intervals. Drip irrigation allows slow and precise delivery of water around the root zone, saving about 60% of water in all soil types compared to bucket irrigation without reducing yield. It also helps to mature the crop earlier; in the case of bitter gourd, the harvest was three weeks earlier than usual. This helps the farmers to sell the product for a higher price. Drip technology saved 50% in labour compared to the conventional method of bucket irrigation. Drip irrigation is very useful for growing spaced crops on level ground. Due to more efficient water use, drip irrigation helps to increase the area under vegetable cultivation and in a few cases allows cultivation of fallow land (after monsoon crops), which contributes to additional household income. About 100 farmers in the watershed have now adopted drip irrigation, and the area under vegetable cultivation has increased.


Figure 27: A drip irrigation system

Table 12: **Water requirement** (Source: Annex 6, Table 4)

Year 2004	Area in ha	Crop water requirement in m^3					
		March		April		May	
Crop grown		1	2	1	2	1	2
Tomato	192	151,660	185,914	279,102	351,695	334,988	167,050
Spring vegetable	83	33,930	62,402	121,972	138,664	130,226	82,777
Total crop water requirement in m^3		185,590	248,316	401,074	490,359	465,214	249,827
Crop water requirement pre-monsoon in m^3		2,040,385					

Sprinkler irrigation is another option for efficiently irrigating high-value cash crops. This method was demonstrated at different locations in the Jhikhu Khola watershed (Figure 28). At the beginning (2002 and 2003), PARDYP supported 15 farmers. A farmers' perception survey was carried out in 2004 to assess the condition and performance of the sprinkler systems. The farmers had been using the technology with different cash crops on areas of 64 to 1,524 m^2. Sprinkler irrigation was used to irrigate up to six vegetable crops on a rotational basis. About 80% of farmers had been growing garlic, 70% onion, 55% cabbage, 45% cauliflower, 20% shallots, and 10% potato. A few farmers were also growing bitter gourd. Most of the farmers collected tap water in a traditional pond (wastewater collected after household use), which then flowed through a polythene pipe to run the sprinkler. Some also used water from an irrigation canal and a few from water harvested from the roof (during the monsoon) stored in a cement jar.

Figure 28: Sprinkler irrigation

Farmers thought that sprinkler irrigation had the following advantages:

- it is appropriate for irrigating sloping as well as level land;
- it saves time – once installed and sprinkling it does not need to be looked at for 3-4 hours;
- it provides uniform application of water;
- it reduces soil loss from sloping land and increases soil moisture;
- it is easy to handle and transport to the desired location;
- a single set is sufficient for 2 to 3 households;
- the water drives away insects;

and the following disadvantages:

- it requires frequent maintenance against blockage of holes;
- it needs sufficient head pressure and is therefore not very useful for flat land;
- sometimes it stops functioning (does not rotate at all and disconnects from the main pipe).

The differences perceived by farmers between drip and sprinkler irrigation systems are summarised below.

Sprinkler Irrigation	Drip Irrigation
Useful in closely grown crops such as garlic and onion	Useful for crops planted widely apart such as bitter gourd and cauliflower
Can be used on sloping land	Difficult to use on sloping land
Easy to transport, and possible to use for different crops in rotation	Difficult to transport; it is fixed for one crop and stays the whole growing season
Repels insects	Does not repel insects
Easily available in local market and cheap	Not easily available in local market and expensive
Requires more water therefore requires perennial water source	Requires less water and is highly water efficient
Requires frequent maintenance against blockage	Requires low maintenance
Requires sufficient head pressure, therefore not applicable in flat areas	Low head pressure is adequate for irrigation
Likely to be stolen because of easy dismantling	Difficult to dismantle once crop is grown

Another useful approach for reducing crop water requirement is the **system of rice intensification (SRI)**. In this system, 8-12 day-old 2-leaf seedlings are planted at a wide spacing (generally 25 cm x 25 cm or even wider). Only a small amount of water is applied when the field is prepared for transplanting, and the fields do not require continuous flooding except during the flowering stage. If the land starts cracking due to drying, light irrigation is required to moisten the soil. Alternate dry and moist soil conditions improve aeration thus helping the plants to grow vigorously. PARDYP tested SRI in the Jhikhu Khola watershed as an option for improved productivity, both in the complex of the Spice Crop Development Center and on farmers' fields (Figure 29). Farmers found that SRI consumed 50 to75% less water than the traditional method. It reduced frequency of irrigation, conflict among irrigation water users, and riser failure caused by stagnant water (see Annex 12 for details). However, it is essential to have full control over the irrigation and drainage.

Different crops require different amounts of water; therefore **modifying cropping patterns** can also help to mitigate water scarcity to some extent. A case study was analysed on the Juke irrigation canal – one of the large irrigation canals in the Panchkhal valley irrigating about 45 ha of valley agricultural land. The total crop water requirement for the current cropping pattern is about 1.66 million m^3 of irrigation water annually. In addition to the water provided by existing irrigation canals and rainfall, the present cropping pattern demands additional irrigation water of 598,600 m^3 for optimum growth. Modifying the cropping pattern in various ways can significantly reduce the additional water requirement (Table 13 and Annex 13). Population growth, agricultural intensification, and gradual advancement of people's lifestyles, have increased water demand (Figure 30). Rainfall records do not indicate any significant change in the climatic pattern over the last 50-60 years. Difficulties in water availability are inherent in the seasonal characteristics of the monsoon and exaggerated by human behaviour. Changing cropping patterns is an appropriate way to help manage potential water deficits.

Figure 29: System of Rice Intensification

Table 13: **Additional irrigation water requirement**

	Additional irrigation water requirement in m³					
	Pre-monsoon	Mon-soon	Post-mon-soon	Winter	Total	Reduction from present pattern
Present cropping pattern	375,114	32,540	24,205	166,749	598,609	
Changing wheat to oil seed	371,869	32,540	17,200	146,897	568,506	30,103
Changing 50% of the potato to winter vegetable	375,114	32,540	17,752	149,964	575,371	23,238
Changing wheat to oil seed and 50% of the potato to winter vegetable	371,869	32,540	17,200	132,496	554,105	44,504

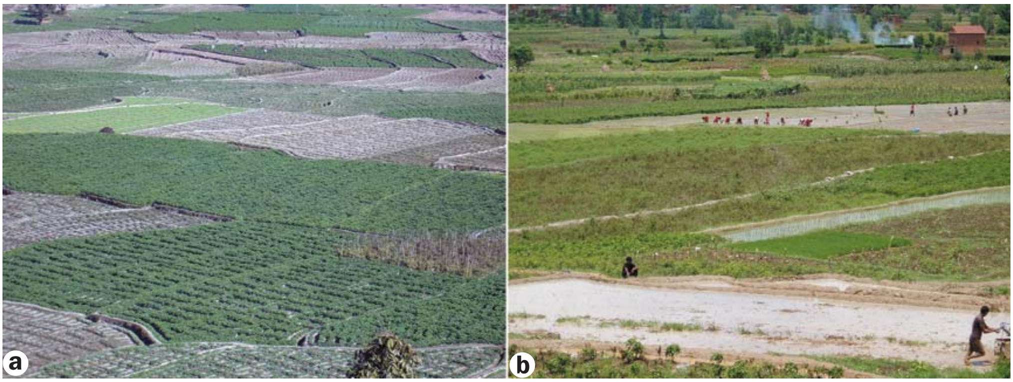


Figure 30: Intensive cropping patterns a) winter b) summer

Lessons Learned and Recommendations

Water demand and supply

- Total domestic water demand in the Jhikhu Khola watershed has more than doubled over the last 15 years (1990-2004) due to increased population.
- Agricultural water use in the Jhikhu Khola watershed has increased by about 4 million m^3 over the last 10 years (1994-2004).
- Annual rainfall in the watershed varies, but long-term data do not show any decrease in annual rainfall.
- Water scarcity in the watershed seems to be caused by increased demand rather than reduced rainfall.

Management options

Improved infiltration

- Levelling sloping agricultural land increases infiltration thereby improving soil moisture and reducing nutrient loss, which help productivity.
- Terraces can be developed over two or three years by introducing biological barriers and using appropriate cultivation practices.
- Eyebrow pitting is a very good way of increasing soil moisture status, creating a favourable micro-environment for plants to grow.
- Protecting a spring source and its catchment area from pollution improves water quality.
- Vegetative measures in the catchment area improve the water regime of a spring.
- Collecting spring water in a tank improves water availability.
- Flow measurement in a spring can play a crucial role in preparing strategies to reduce conflict in areas of water scarcity.

Water harvesting

- Storing water in conservation ponds is an important option for meeting water demands.
- The local technology of lining ponds with a clay layer and puddling reduces seepage loss in earthen ponds.
- High density plastic sheet or SILPAULIN is an effective lining material to reduce seepage loss.
- Large underground cisterns are dangerous, costly, and not recommended in earthquake-prone hill areas, and are generally not applicable for irrigation because of the size required to store enough water.
- Underground cisterns could be used to store drinking water to reduce evaporation loss.
- Wells are an important source of water to manage water scarcity.
- Wells located close to the top of a continuous ridge recharge quickly with the onset of rain.
- Water table fluctuation in wells close to streams is low, but high in wells located close to the top of a continuous ridge.
- The water table in wells located at the foot of a slope decreases with decreasing rainfall.
- Roof-water harvesting is an important option to fulfil the needs for drinking water in water scarcity areas.
- A minimum of 1,000 litres storage is essential for useful roof-water harvesting. Although water need is greatest from October to March, more water can be collected from May to September, and roof-water harvesting is generally more pragmatic during this period.
- The overall annual water status for agricultural land in the Jhikhu Khola watershed is in surplus, except for irrigated land in the lower zone. However, all agricultural land had seasonal water scarcity with a particular deficit from October to April.

- Runoff harvest can potentially fill a significant additional crop water requirement for rainfed land in September and November in the upper zone and from September to February in the lower zone of the Jhikhu Khola watershed.
- The recommended pond size for a collecting pond for surface runoff to fill the additional water requirement for a hectare of rainfed land is 200 m^2 with an effective pond height of 1.25 m in the upper zone and 125 m^2 in the lower zone of the Jhikhu Khola watershed. The recommended catchment area is 3 ha in the upper zone and 2 ha in the lower zone.
- Water harvesting measures such as conservation ponds and irrigation canals not only fulfil crop water requirements but also conserve sediment and nutrients.
- Further research is needed on runoff harvest coefficients, stream flow coefficients, and the water requirement of other crops.

Efficient water use

- Drip irrigation is an efficient option for crops grown on level surfaces at a distance from each other such as bitter gourd and cauliflower; it saves up to 60% of water compared to bucket irrigation without decreasing production.
- Drip irrigation saves about 50% of labour compared to bucket irrigation.
- Drip irrigation helps crops to mature earlier, enabling the farmers to get better prices. The early maturation is due to uniform moisture availability for efficient photosynthesis.
- Drip irrigation is not an appropriate option for closely grown crops such as garlic and onions.
- Availability of drip irrigation equipment is still a constraint in the hills of Nepal.
- Sprinkler irrigation is a time saving irrigation option for closely grown crops in the hills where sufficient head pressure can be easily achieved.
- The SRI allows paddy fields to be cultivated with less water, which helps to reduce irrigation conflict in the community.
- SRI increases yield and requires less inputs such as seedlings and labour than traditional methods.
- For successful SRI, it is essential to control irrigation and drainage to maintain soil at the right moisture level.
- Modifying cropping patterns can reduce crop water requirements to some extent, and therefore could be an important strategy in irrigation water management.

4 WATER QUALITY

Background

Deterioration of water quality is an increasing concern in many parts of the world. Pollution of water sources in rural areas due to human waste and use of chemical fertilisers and pesticides is a problem in large areas of the middle mountains in the Himalayan region. During the rainy season, faeces and other pollutants are washed into river systems and water sources, adding to the health risk. The Jhikhu Khola watershed is no exception to these issues. In the Water Demand and Supply Survey, 17% of respondents in Jhikhu Khola and 9% in Yarsha Khola mentioned the problem of drinking water quality (Merz et al. 2002).

The question that PARDYP sought to answer was ***'What is the status of water quality and how can drinking water quality be improved'?*** Water quality was monitored and different options tested.

Water Quality Monitoring

PARDYP conducted a survey of water sources and monitored the water quality of a large number of public sources such as springs, streams, dug wells, and rainwater harvesting jars (Figure 31). Monitoring was carried out during four seasons over a number of years: pre-monsoon (March-May), monsoon (June-September), post-monsoon (October-November), and winter (December-February). The data were analysed and compared with the 1997 World Health Organization guidelines to quantify the water quality status.

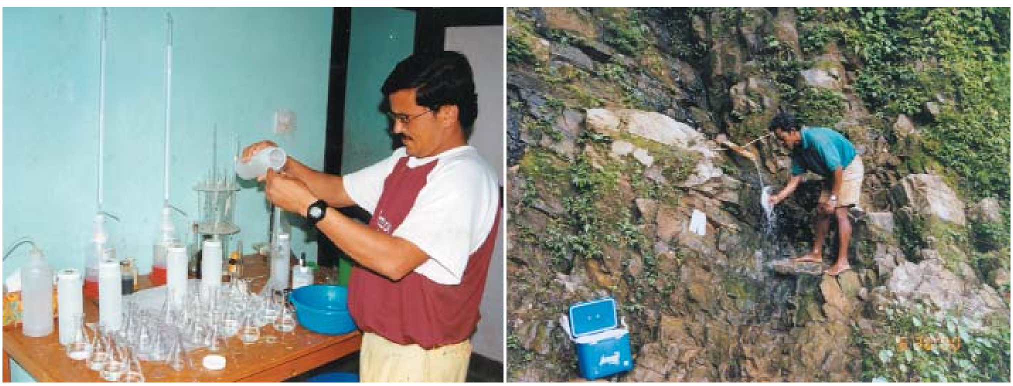


Figure 31: Collection and investigation of samples from drinking water sources

Springs

Basic physical and chemical parameters were investigated in a total of 319 springs in the Jhikhu Khola and 215 springs in the Yarsha Khola watersheds (Annex 14, Table 1). The majority of the springs in both watersheds had a turbidity of less than one nephelometric turbidity unit (NTU). In terms of pH and electrical conductivity (EC), water quality was better in the Jhikhu Khola than in the Yarsha Khola springs (Annex 14, Table 3). All other water quality studies were carried out in the Jhikhu Khola watershed only.

Microbiological and other contamination

Total and faecal coliform contamination was very high in **stream water** at all sites tested. Phosphate was above the European Commission (EC) recommended limit of 0.4 mg/l at about 60% of the stream sites. Turbidity was high (> 25 NTU) in most seasons but particularly so in pre-monsoon and monsoon (Annex 14, Tables 4 and 5).

Total and faecal coliform/E. coli contamination was very high in all **spring sources**. Phosphate exceeded the EC limit in more than 50% of the spring sources; however, the springs in the Kubinde area and the Barabot spring in the Dhotra area had phosphate levels within the limit (Annex 14, Tables 6 to 10).

Total coliform and faecal coliform/E. coli contamination was very high in all the **shallow dug wells** investigated. Phosphate exceeded the EC recommendations in most cases. High turbidity was observed especially in the pre-monsoon and monsoon seasons. Ammonia was also a problem in a number of wells, especially in the monsoon season. The pre-monsoon and monsoon seasons were more problematic generally than other seasons (Annex 14, Tables 11 and 12).

Total coliform and E. coli contamination was found in the majority of **rainwater harvesting jars** investigated, particularly in the pre-monsoon and monsoon seasons. Phosphate was above the EC limit in a number of jars; the pH was mostly above 8 (Annex 14, Table 12).

Water Quality Improvement Options

PARDYP tested various options for addressing drinking water quality issues, including organising dissemination and awareness building workshops, solar water disinfection (SODIS), low cost water filters, and a case study on spring source protection with community participation.

Awareness building

PARDYP organised a number of workshops for local residents, authorities, science teachers, school children, and health volunteers to discuss and present the water quality status and potential treatment measures. People were made aware of water quality problems, health, and sanitation improvement systems. Pamphlets on low-cost water filters and SODIS were disseminated and the methods promoted. People were trained to tackle the microbiological problems of drinking water by using methods such as boiling, chlorination, SODIS, and low-cost water filters.

SODIS (solar water disinfection)

SODIS is a simple, cheap, and environmentally friendly technology which consists of putting clear water into PET bottles and exposing it to sunlight for about eight hours. Ultraviolet rays in the sunlight kill any microorganisms in the water. This is a laboratory tested and proven technology. PARDYP tested the technology in the Jhikhu Khola watershed and found it very effective for disinfecting microbiological contamination in drinking water. About 50 local residents from different parts of the Jhikhu Khola watershed were given training and orientation on the SODIS technology. It was also disseminated to the people in the Baluwa area in the Jhikhu Khola watershed through Rani Pani Gram Sewa Kendra, a local non-government organisation (NGO). People were also provided with pamphlets explaining how to use the method properly. They found it very easy and useful. The main problem was that it was difficult to find PET bottles in rural areas. SODIS was mainly useful for household consumption; it was not practical to carry large quantities of water to farmers working in the fields. People also felt that the water in the plastic bottles became warm and lost its natural taste. For these reasons and the lack of health consciousness, SODIS has not been scaled up and was not popular. Very few people practise it.

Low cost water filter (SAFA filter)

A low cost water filter (SAFA filter) developed by International Development Enterprise was applied locally with two plastic transparent buckets containing a silver-coated ceramic candle and outflow tap. This candle filters about 2 l/h of water, which was quite efficient compared to other water filters available in the market. PARDYP tested this technology in the Jhikhu Khola watershed and found the silver coated candle used in the SAFA filter to be highly effective in removing turbidity and coliform contamination from the water. As the buckets were transparent, it was easy to see the clean filtered water in the lower bucket. About 20 sets of this filter were tested and disseminated to the local residents who found it a very appropriate option for improving drinking water quality. However, due to poverty, lack of health consciousness, and lack of availability of the SAFA filter in the rural market, the method did not become popular and was not scaled up and replicated. There were also some quality problems with fitting of filters. Without proper handling, cleaning, and maintenance, the SAFA filter will not give pure and clean water.

Case study: Water quality management – Barabot Spring, Dhotra

A case study was conducted on Barabot spring at Dhotra in the Jhikhu Khola watershed to test and disseminate promising water management options for more efficient use and equitable access. Management of drinking water quality was a part of the study. Barabot spring was a natural spring without any structure and the source was in very poor condition. The water was turbid and microbiologically contaminated. The community had no alternative source nearby. The case study included monitoring water quality seasonally, community mobilisation, motivating user groups, structural improvement of the source with a closed spring box (Figure 32), source and catchment protection, and creating user awareness of water quality problems and health issues. After the new measures were introduced, the water became clear and microbiological contamination was reduced. The users became aware of water quality problems, water conservation methods, and proper sanitation. They were also given household-level treatment options like chlorination, solar water disinfection (SODIS), and low-cost water filters. Of these, users preferred the low-cost water filter as it is simple and easy. The case study showed that participatory and integrated management can effectively address water problems.

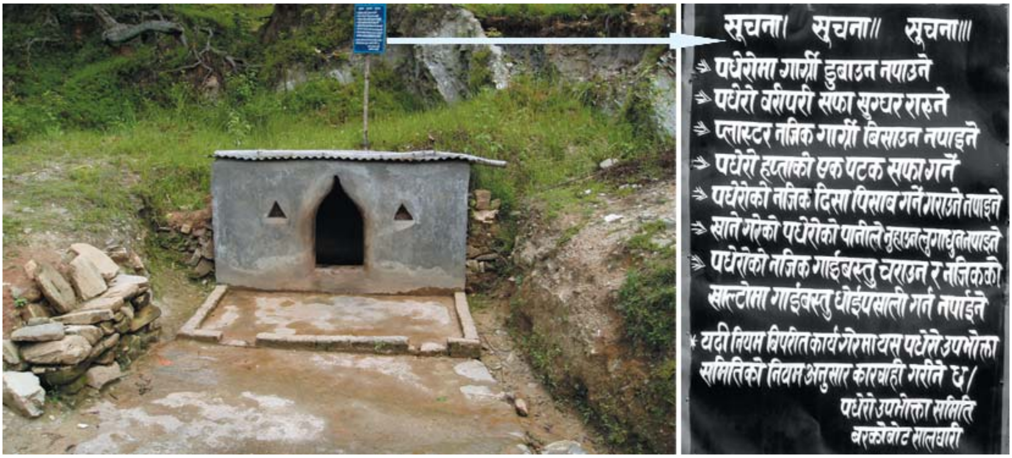


Figure 32: Protected spring at Barabot Dhotra, showing the user rules

Lessons Learned and Recommendations

- Microbiological contamination was the main problem in all types of drinking water sources.
- All sources were unsafe for drinking without treatment irrespective of the season, although during winter the quality of drinking water was better.
- Contamination is due to poor sanitation systems and seepage, the poor structure of water sources, and the poor handling of water.
- Phosphate was a problem in many of the sources, indicating agricultural pollution. Nitrate was within the World Health Organization guideline value.
- Seasonal water quality analysis did not show any distinctive pattern of the water quality parameters, but did show that water during the pre-monsoon and monsoon was more polluted.
- It is recommended that water from any source should be treated by boiling, addition of bleaching powder or chlorination, solar disinfection (SODIS), or low-cost water filter as short term solutions.
- Long-term measures to protect sources and their catchments are urgently required.

5 On farm

Some of the major concerns related to livelihood improvement are maintaining soil fertility, degradation of community lands, increasing farm income, building capacity of the community, and decreasing women's workloads. Several questions arose concerning these issues and PARDYP tested and synthesised a number of options to address them.

How Can Farmers Maintain or Improve Soil Fertility?

Soil fertility is a key concern of every farmer. Soil fertility can be supported through appropriate agronomic practices as well as appropriate use of fertilisers. PARDYP tested various agronomic practices in the different project watersheds. The main agronomic practices considered were inter-cropping, crop rotation, mulching, and liming. The main soil fertility management options were pit composting, black plastic composting, vermicomposting, and use of effective micro-organisms (EM) (rhizobium, azatobacter, and boakshi). The tests in PARDYP-Nepal focused on on-farm composting using black plastic and EM, and lime application in acidic soils. PARDYP-Nepal also monitored leachate in the soil erosion monitoring plots in agricultural and degraded land to help understanding of the nutrient dynamics in the soil profile.

On-farm composting

Compost or farmyard manure has played a crucial role in maintaining and building up soil fertility in Nepal. Many different composting methods were tested and demonstrated in the Jhikhu Khola watershed. Among the different methods, farmers considered **black plastic covered composting** as recommended by the Sustainable Soil Management Project to be the best.

Black plastic composting was first tested with 16 farmers in 2004. By 2005, about 50 farmers had started using this method in the Jhikhu Khola watershed. In this method, a traditional compost heap is covered with a piece of black plastic, which protects nutrients from leaching during rainy days and provides a favourable environment (increased temperature and decreased evaporation loss) for the growth of microbes (Figure 33). The method is based on a passive aeration approach, the black plastic is removed from the compost heap for a short period each day. Using this method, compost decomposed within 45-50 days compared to about 4-6 months without the plastic sheet. Black plastic (thickness ~ 800 μm) is light, easy to use, and durable. Compost is produced with less time and labour than by the standard method.

Use of **effective micro-organisms (EM)** is another method being adopted by the watershed residents. In this method, composting is based on aerobic decomposition and

Figure 33: On-farm composting with black plastic cover

Figure 34: Composting with effective micro-organisms (EM)

again it takes about 45 days to decompose fresh materials rather than 4-6 months. Effective micro-organisms (EM) refer to a mixed microbial culture of selected species such as lactic acid bacteria, yeasts, photosynthetic bacteria, and actinomycetes. All of these are natural, compatible with one another, and coexist in liquid culture. In this method, locally available raw organic materials such as crop residues, plant leaves, and grasses are used as fertilising resources. The ingredients are mixed together and piled in multiple layers; the EM solution is sprinkled between layers together with old compost as microbial inoculums. Water is also sprinkled on each layer to ensure the moisture content. The pile is covered with a plastic sheet; 3-4 wooden poles are inserted vertically to provide sufficient ventilation, and the pile is turned every 10 days (Figure 34). Moisture status is monitored and water is sprinkled on the heap if deficiency is observed. The general practice in the Jhikhu Khola watershed is to use about 1,000 kg of the fresh ingredients, about 500 litres of water, 250 kg old compost, and about 1 litre of EM solution. EM is easily available in the local markets and is cheap.

Soil acidification and lime experiment

The soil survey showed that soil acidification problems were similar in both watersheds (Table 14). In both watersheds about 80% of soils tested had a low pH (~5.0). Extensive use of chemical fertilisers (particularly urea and ammonium based fertilisers), presence of partially decomposed pine litter in farmyard manure, and acidic bedrock (sandstone, siltstone, and quartzite) are among the factors contributing to acid soil (Schreier and Shah 1999).

Soil acidification, associated with high inputs of acid-causing fertilisers (urea and ammonium based fertilisers) and acid bedrock geology, is becoming a major problem in the double and triple crop rotation systems in the Jhikhu Khola area. Chitrakar (1990), Sherchan and Baniya (1991), and Suwal et al. (1991) noted that the commonly used fertilisers, ammonium sulphate and urea, tend to acidify soils. This acidification has serious implications as low soil pH (< 5.0) slows the rate of organic matter decomposition, and leads to the leaching of base cations (calcium and magnesium) and the fixing of available phosphorous in the soil – making it unavailable to plants – and to aluminium toxicity and micronutrient deficiencies (Shah 2003).

Table 14: Soil pH in the watersheds

	Soil pH	
	Jhikhu Khola watershed	Yarsha Khola watershed
Mean	4.65	4.75
Maximum	6.70	7.42
Minimum	3.97	3.59
Sample Number	200	340

Source: Schreier and Shah 1999

PARDYP investigated whether pine litter in compost was contributing to soil acidification on red soils originating from phyllitic parent materials and brown (non-red) soils from quartzitic materials. Twelve 50 x 50 cm plots were established; six plots each were assigned for red and non-red soils. Plots of one red and one non-red soil were combined to make six sets of treatments. In the first set of plots, 1 kg per m^2 of dry pine litter was incorporated, and the same amount of pine litter was added 2 times in the 2nd, 3 times in the 3rd, 4 times in the 4th, 5 times in the 5th, and 6 times in the 6th set at intervals of six months. The soil was analysed for pH, exchangeable cations, carbon, and available phosphorous (Bray-1) using standard procedures (after Schreier and Shah 2000). 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. While the carbon and calcium content improved with pine litter addition, the pH decreased. In the non-red soils, the available phosphorous 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 phosphorous availability in the red soils is impaired. While there are benefits from improving carbon and calcium 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 to have a positive impact on nutrient management (Schreier and Shah 2000). Earlier PARDYP experiments showed that acidification is a slow process and that different soils respond differently. In general this is a long-term problem seen by researchers, but farmers tend not to see it as a serious problem because it is not yet affecting their yields.

Intensification and in particular cash crop production has influenced the nutrient budget and soil nutrient pool of irrigated and rainfed lands. No changes were observed in soil pH between intensively and less intensively farmed sites, but a slight decline was noted in irrigated fields and a slight increase in rainfed fields. Intensification has not led to more acidic soils as the soils are already acidic and would probably need higher levels of acidic inputs to cause further acidification. Also the calcium-enriched irrigation water tends to buffer the effects of soil acidity in irrigated sites (Shah 2003).

PARDYP tested the effects of applying lime to the acidic soils of the Jhikhu Khola watershed. Eight sites with low soil pH were selected. A recommended dose of lime was applied to five ropanis of land (1 ropani = 508 m^2) by each of three farmers (three sites) in Lamdihi to test its effects on maize – for example: 120, 230, and 294 kg of lime per ropani on clay loam soil with pH 6.0, 5.5, and 5.2 respectively, as per Agriculture Development Diary 2005 (AICC 2005). Likewise, lime was applied to five vegetable farming sites (cauliflower, potato, tomato, and brinjal). At each site control plots were established, and soil pH and production before and after lime application studied. The results showed a slight increase in soil pH (by 0.1-0.3) after one crop season following lime application. Interestingly, the production of potato increased by about 50% in plots where lime was applied. A few research farmers pointed out that it was easier to till the land after lime application. The effect of lime on soil pH and production demands much more intensive scientific study, including cost:benefit analysis, proper design, and accuracy of measurement.

Leachate Study in the Jhikhu Khola Watershed

Nutrient loss through leaching reduces soil fertility and thus production. PARDYP monitored leaching in its soil erosion monitoring plots on agricultural and degraded land to understand the nutrient dynamics in the soil profile, which might be very important for sustainable soil fertility management.

The leachate volume (6 to 58% of rainfall) in rainfed agricultural land was significantly higher than runoff (2 to 7% of rainfall), whereas in degraded land the leachate volume (12 to 16% of rainfall) was slightly lower than runoff (18 to 29% of rainfall). The total leachate volume was higher in agricultural land than in degraded land, ranging from 541 to 4,712 m^3/ha in rainfed agricultural land and from 389 to 865 m^3/ha in degraded land. The reason might have been the effect of the red soil in the degraded plot, which was very compact due to inadequate vegetation resulting in low infiltration. The agriculture plots were somewhat levelled, and due to soil working for cultivation, infiltration in agricultural land is significantly higher than in degraded land. Also, farmers apply chemical fertilisers to rainfed agricultural land while no chemical fertilisers are applied to degraded land (see Annex 15).

In rainfed agricultural land, nitrate leaching ranged from 306 to 2,518 kg/ha, which is equivalent to 147 to 1,230 kg/ha of urea fertiliser. Leaching of nitrate from degraded land ranged from 59 to 237 kg/ha, equivalent to 29 and 115 kg/ha of urea fertiliser. Phosphate leaching ranged from 5 to of 94 kg/ha in rainfed agricultural land, equivalent to 3 to 66 kg/ha of diammonium phosphate (DAP) fertiliser, while from degraded land it ranged from 1 to 5 kg/ha, equivalent to 1 to 3 kg/ha of DAP fertiliser. Potassium leaching ranged from 41 to 801 kg/ha in rainfed agricultural land, which is equivalent to 68 and 1,334 kg/ha of murate of potash fertiliser, and from 52 to 160 kg/ha in degraded land, equivalent to 86 and 267 kg/ha of murate of potash fertiliser (see Annex 15). Among the three nutrient parameters, nitrate was most leached from the soil, followed by potassium and then phosphate. Phosphate leaching was comparatively small.

How to Rehabilitate Degraded Land

Degraded land is a major problem in the Jhikhu Khola watershed, and rehabilitation of degraded land is one of the major concerns of local people. Degradation is common on communal lands as well as on rainfed sloping agricultural (bari) land. PARDYP tested two major options to improve these lands: rainfed hill terrace improvement and rehabilitation of degraded communal lands.

Rainfed hill terrace improvement

In Nepali, improvement of rainfed hill terraces is known as 'gara sudhar'. Rainfed sloping agriculture is very common in the mid-hills of Nepal. Soil fertility is maintained by adding compost and/or fertiliser, but most of the added nutrients are usually washed out in the first rains of the monsoon season. Soil erosion, nutrient leaching, high runoff, and low soil moisture status are major concerns on this type of land. At the same time, the productivity of the crops grown and the scope for crop diversification is limited by the slope. PARDYP joined with the Nepal Government's Department of Soil Conservation and Watershed Management to test and demonstrate rainfed hill terrace improvement with farmers in the Jhikhu Khola watershed. The improvements involved slope correction of the terrace (thus increasing terrace stability), conserving soil nutrients and moisture, and planting nitrogen-fixing hedgerow species along the terrace margins in single or multiple rows (thus increasing fodder availability, reducing erosion and runoff, and stabilising the riser). All technical activities were performed manually using locally available tools and materials. The species preferred by farmers in the Jhikhu Khola watershed for terrace stabilising were:

1) **grasses:** napier (*Pennisetum purpureum*), molasses (*Melinis minutiflora*), and stylo (*Stylosanthes guianensis*);
2) **shrubs:** sunhemp (*Crotalaria juncea*), tephrosia (*Tephrosia candida*), and flemingia (*Flemingia macrophylla*).

Typical plantations are shown in Figure 35.

As a result of levelling and planting of vegetative hedgerows, the slope of agricultural land was reduced from about 30% to around 5%. The technology took about a year to be fully established and cost approximately USD 1,300 per ha during the establishment phase including labour and USD 340 per ha for maintenance. The activity was carried out by the farmers themselves; PARDYP supported 25% of the total cost of the activity in the establishment phase and of the planting materials in the following years.

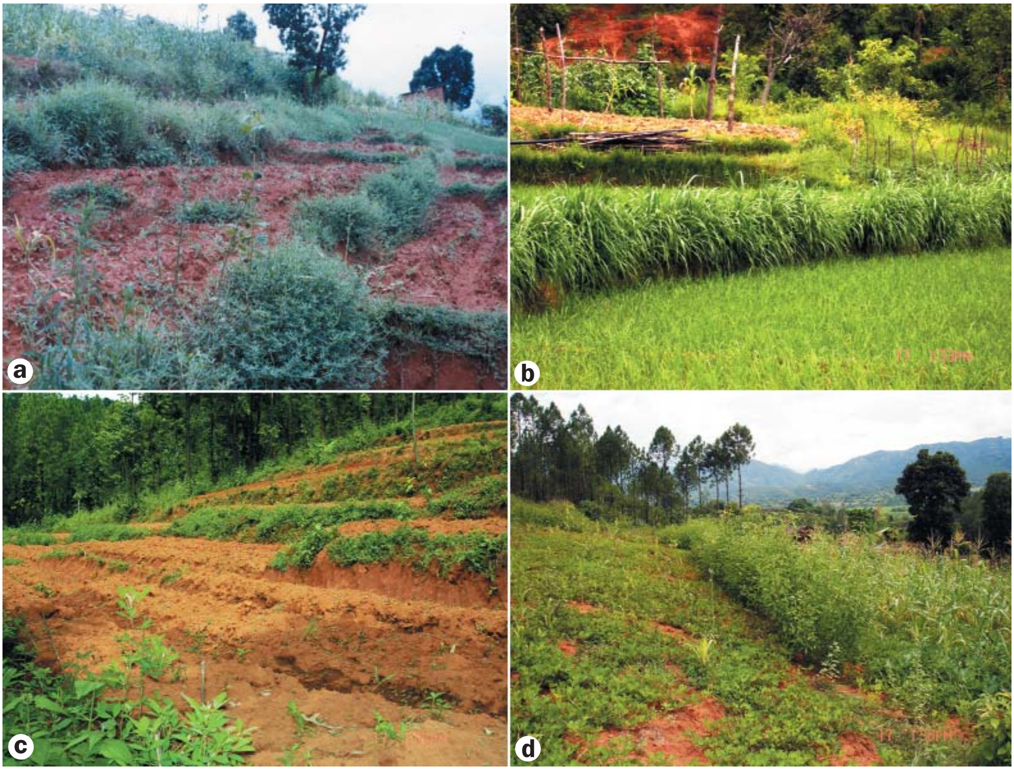


Figure 35: Grasses planted during improvement of rainfed hill terraces
a) Molasses (*Melinis minutiflora*) and stylo (*Stylosanthes guianensis*) along a terrace;
b) Napier (*Pennisetum purpureum*) along a terrace riser; c) Stylo (*Stylosanthes guianensis*) on a terrace riser; d) Sunhemp (*Crotalaria juncea*) hedgerow planted along a contour

Some of the benefits farmers observed from the technology are:

- less soil erosion, rill erosion, and nutrient leaching compared to the traditional sloping agricultural land;
- increase in soil moisture due to reduced slope and improved efficiency of fertiliser input, leading to better yields;
- reduced movement of sediments downstream;
- increase in the selling price of land due to improved conditions of the land and better production capacity;
- increased fodder and grass production from the land, thereby reducing the workload of women, who are traditionally entrusted with collecting fodder;
- hedgerow species such as tephrosia and sunhemp have benefited other crops; first they serve as stakes for cash crops, and secondly the crop yield has improved due to their nitrogen-fixing properties.

Farmers in the watershed are now gradually adopting this technology.

Rehabilitation of degraded lands

Figure 36: Dhotra rehabilitation site, Jhikhu Khola Watershed

PARDYP was involved in rehabilitating various sites in the watersheds. Dhotra Rehabilitation Site near Dhotra Village, a thirty minute walk from the roadhead at Tinpiple in Kabhre District, is a good example of rehabilitation of highly degraded dry land (Figure 36). The site comprised about 2.5 ha of very badly degraded south-facing red-soil land at an elevation of 850-875 masl, with hardly any ground vegetation. The site became degraded due to excessive overgrazing. Two major gullies with small slides threatened a trail and farmland.

PARDYP collaborated with the community and the local Ekanta Basti Yuba Club from Dhotra village to carry out re-vegetation of the barren slopes, and gully control activities.

Moisture stress was the major constraint to growth of vegetation on the site. Due to moisture constraint, planting activities carried out eight years previously had not been successful. The technique of eyebrow pitting was adopted to retain rainwater. In this technique small curved trenches in the shape of an eyebrow facing inward to the slope are dug at intervals to catch water and slowly return it to the soil. Altogether 130 eyebrow pits were dug together with catch drainage trenches. The row-to-row distance between the eyebrows was 6m; the average length, depth, and width were 2m, 40cm, and 50 cm, respectively. The average length of the drainage trenches was 4m and the depth was 20 cm. The eyebrow pitting design is shown in Figure 37.

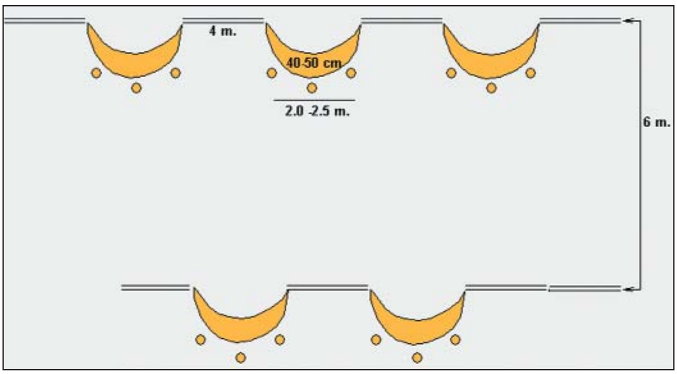


Figure 37: Eyebrow pitting design

Several species of grass and fodder were planted along the ridges of the eyebrows and drainage trenches. Contour hedgerows were planted in between the eyebrows and drainage trenches, and tree species just below the eyebrows (Figure 38). The species used were: sunhemp (*Crotalaria juncea*), tephrosia (*Tephrosia candida*), flemingia (*Flemingia microphylla*), tithonia (*Tithonia diversifolia*), stylo (*Stylosanthesguianensis*),

5 – On Farm

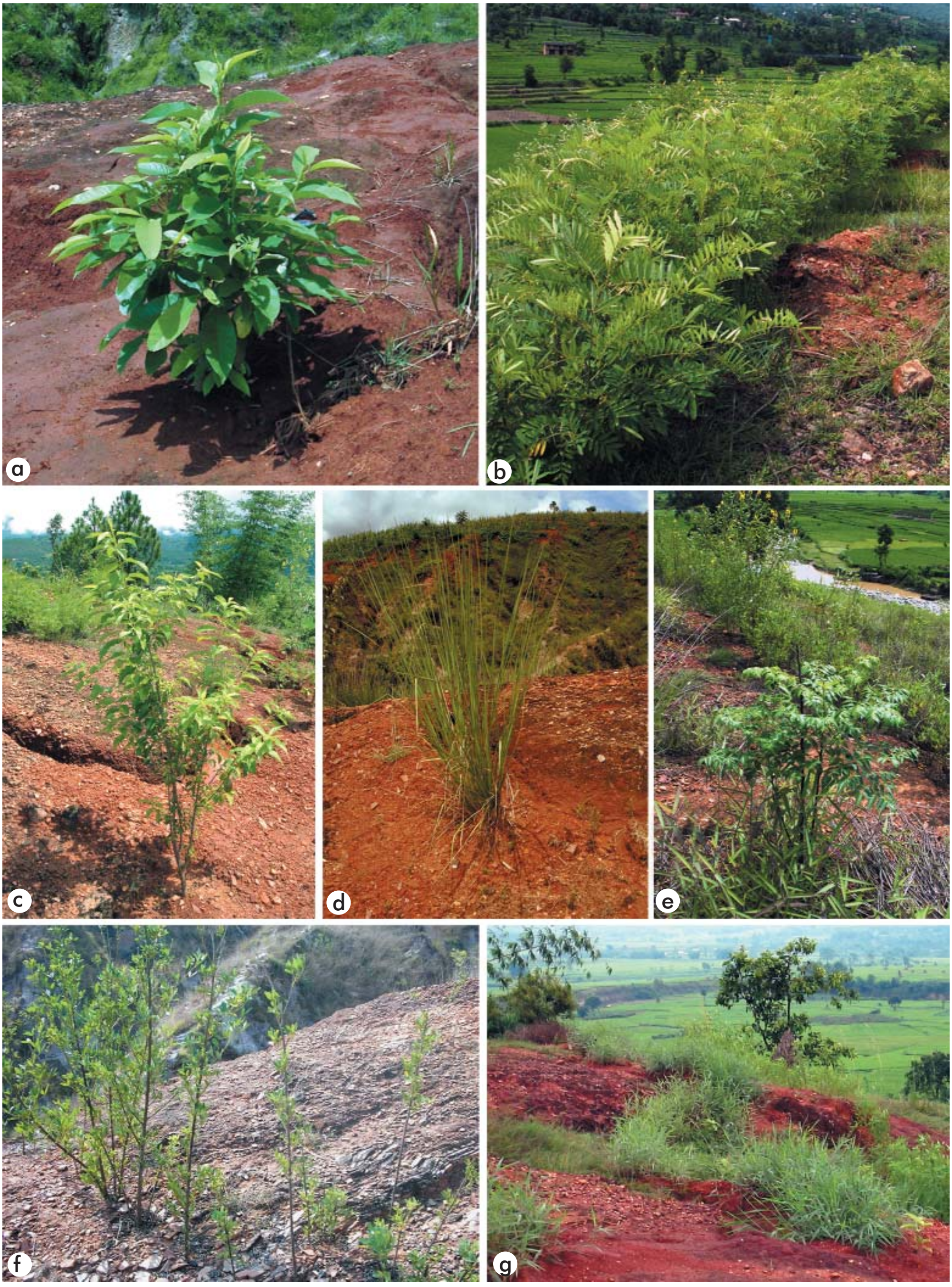


Figure 38: Vegetation planting for rehabilitation of degraded dry land in Dhotra
a) Champ (*Michelia champaca*); b) *Tephrosia candida*; c) Paiyun (*Prunus cerasoides*); d) Vetiver; e) Bakaino (*Azadirachta indica*); f) Sunhemp (*Crotalaria juncea*); g) Molasses (*Melinis minutiflora*)

napier grass (*Pennisetum purpureum*), gini grass (*Panicum maximum*), mollasses (*Melinis minutiflora*), dinnath (*Pennisetum pedecellatum*), wyancassia (*Chanaecrista rotundifolia*), signal (*Brachiaria decumbens*), dhaincha (*Sesbania grandiflora*), and epil-epil (*Leucena leucocephala*). Apart from grass and fodder, tree species such as champ (*Michelia champaca*), bakaino (*Melia azedarach*), chilaune (*Schima wallichii*), lapsi (*Choerospondias axillaries*), paiyun (*Prunus cerasoides*), bamboo, chiuri (*Bassia butyracea*), kalki (*Callistemon viminalis*), kapor (*Cinnamomum camphora*), amba (*Psidium guajava*), nim (*Azadirachta indica*), and amala (*Emblica officinalis*) were planted. The species were chosen using preference ranking derived from a needs assessment survey. About 1,700 hedgerow plants and 1,050 tree seedlings were planted, and 7 kg of grass seeds propagated.

In the gullies, 25 check dams were constructed using soil-filled cement bags. Bamboo was planted on the upper and lower side of each check dam (Figure 39).

Figure 39: Bio-engineering activities for gully treatment

The community participated in all steps of planning and implementation. Women participated much more in all plantation and gully protection activities than men, who only dug the pits for plantation. Men and women participated equally in filling bags. Women comprised 56% of all participants, men 44%.

The implementation of activities started in June 2004. Several meetings were organised and the capacity of a local institution (Ekanta Basti Yuba Club) was strengthened. A user group, all women, was formed for future management, planting, and protection work. Within a year, the community was able to collect a small amount of money by selling grass seed and the results of the rehabilitation were encouraging.

How Can We Increase Farm Income?

Proper and diversified management of farm resources for better production and efficient utilisation of farm inputs are major components for increasing farm income. A number of innovations and new technologies from across the region can help raise farm income significantly. PARDYP tested several options, some of which worked while others did not. The System of Rice Intensification (SRI) was one of the most successful options tested in the Jhikhu Khola watershed. The System of Rice Intensification has been discussed in the context of efficient use of water. Here it is considered in terms of increased production.

System of Rice Intensification

In the Jhikhu Khola Watershed, farmers consider the SRI a potential agronomic option to grow rice especially under controlled irrigation management. In this system, fewer younger seedlings are planted at greater intervals than is the usual practice and grown without flooding except at the flowering stage. The result is markedly improved productivity. PARDYP tested this option on station as well as on farm (Figure 40); the results of the trials are described in detail in Annex 12.

On-station research: at Tamaghat's Spice Crop Development Centre research station, SRI increased Makawnpur-1 rice yields by 10-25% on irrigated land and 10% on rainfed plots.

On-farm research: In 2003, yields in the SRI plots with different rice varieties were 10 to 57% higher than those recorded in traditional plots. The highest yield increase of 57% was recorded for the Naya Parwanipur rice variety, followed by 54 % for Panta 10. In 2004, the yield increase in SRI plots varied from 2 to 67%: 6% for Makwanpur-1; 2 to 45% for Parwanipur; and 67% for Japanese Mansuli. In 2005, the yield increase in SRI plots varied from 8 to 93% with the highest yield recorded for Markwanpur-1 followed by Japanese Mansuli variety and Parwanipur.

Farmers understood that SRI requires only 25% of seeds, 50% of labour for transplanting, 50-60% of labour for irrigation, and less use of pesticide than traditional methods. At the same time there was a 40-50% increase in grain and 20-25% increase in biomass production. This was considered advantageous for smallholder farmers. However, certain problems were encountered with SRI. Extensive weed growth added 50-

Figure 40: On farm action research on SRI

60% to the cost of the first weeding. It was difficult to regulate the irrigation and drainage to keep the land moist or dry where there were no proper irrigation and drainage facilities. Preparation of the 8-12 day seedlings to match with transplanting time, especially under rainfed conditions, was also difficult.

What Approaches Can be Used to Build the Capacity of Communities?

PARDYP followed a participatory action research approach to prepare communities to steer development according to their needs. This is illustrated in the following examples.

Entry point activities: using farmers' priorities to develop collegial participation

Case Study: Mule trail at Kabre village, Yarsha Khola watershed

In December 1999, PARDYP in collaboration with the Department of Forest and Department of Soil Conservation and Watershed Management organised a meeting at the District Development Committee in Dolakha to discuss activities to be undertaken by PARDYP during its second phase. This meeting refined the activities proposed in the previous meetings held at the District Development Committee (DDC) Charikot and Village Development Committee (VDC) Yarsha Khola watershed.

DDC and VDC representatives, schoolteachers, community-based organisation representatives, and farmers prepared a list of research and development activities required for their VDCs. PARDYP's main task was to carry out natural resource management related research activities. During the discussion, the VDC Chairperson of Kabre, another village in Dolakha district, proposed improving the mule trail as their priority activity. PARDYP supported this as an entry point activity to build a good rapport with the VDC and the villagers, and to engage them in the natural resource management research. After a detailed proposal from the VDC in March 2000, and a request from PARDYP/ICIMOD, SDC agreed to partially support completion of the proposed trail to improve the safety of passage for local people and project staff, especially during the monsoon period (Figure 41).

Although this intervention was not a planned activity of PARDYP, it turned out to be one of the most popular and highly appreciated activities with the villagers. As a result a good rapport was built with the VDC and local residents, which ultimately helped PARDYP to conduct research with different stakeholders in a collegial way.

Figure 41: Improved mule trail

5 – On Farm

Improvement of the trail connecting Bagar with Jyamire

The population of the three VDCs (Kabre, Mirge, and Gairimudi) used this trail extensively to reach the roadhead at Minapokhari and to visit the weekly market at Bagar. The biggest part of the trail improvement included mending damaged steep slippery slopes and watercourses (the most difficult part), which were a major problem, especially for schoolchildren, during flooding. The trail was 406m long with an average width of 1.2m. Concrete, cement, and stones were used to make steps on the steepest slopes and stone soling was done on level sections. The trail included three small culverts (underground channels to carry water) to cross the small streams and an irrigation canal. Two big reinforced culverts were constructed over the Khahare Khola using cement, stone, sand, and iron rods.

Construction work started in August 2000 under the supervision of the VDC chairperson of Kabre, and with the participation of the local people. The work was successfully completed in October 2000.

Participatory action research

Participatory action research methodology pursues action and research at the same time. It aims to change an organisation or community by increasing knowledge and understanding through learning by doing. There are several forms of action research. In participatory action research, the researchers (as facilitators) and villagers jointly diagnose problems, their causes, and possible solutions (Figure 42). An example of such research conducted by PARDYP was micro-irrigation combined with high-value cash crops (vegetables).

The PARDYP Water Demand and Supply Survey conducted in 1999 (ICIMOD 2002c) identified irrigation water shortage during the dry season as a major concern for farmers. Several village-level discussions were held in the Jhikhu Khola watershed to identify the possible causes of water shortage, which crops were adversely affected, and the practices and technologies adopted by farmers to cope with the situation. The advantages and disadvantages of the different technologies, and farmers' opinions

Figure 42: Participatory action research in the field

about micro-irrigation systems (drip and sprinkler) were discussed in detail. Drip irrigation was a new technology for the Jhikhu Khola watershed and it was decided to test its performance first in the government's Horticulture Centre at Tamaghat and with a few farmers in a Kubinde village. In the Horticulture Centre, the system was tested on bitter gourd and jointly monitored by the Horticulture Centre and PARDYP; in Kubinde village it was tested on cauliflower and monitored jointly by the participating farmers, the Institute of Engineering-Pulchowk, and PARDYP. Farmers' visits to the Horticulture Centre were organised during the technology testing phase. Formal and informal discussions were organised with the farmers who visited the centre, experiences shared, and interested farmers identified for further research (Figure 43).

Figure 43: Village-level interaction programme

Drip irrigation was tested in 2002 on vegetables (mostly bitter gourd) in 11 fields in different villages located at different altitudes. Training sessions were organised on establishing and maintaining the system; farmers actively participated in every activity (planting, watering, netting, and so on). The water requirement, cost, benefit, advantages, and disadvantages of both systems were analysed.

Village-level focus groups of old and new farmers were organised to evaluate the research results and share experiences on all the aspects of drip and traditional irrigation methods. Most farmers found the technology very effective, except for a few from higher elevations where water availability was higher.

The approach was repeated in 2003 to 2005 with more farmers. In the areas where drip irrigation was less effective, research was started on sprinkler irrigation. The results of sprinkler irrigation were also very encouraging. In 2006, more than 100 farmers were using drip irrigation in the Jhikhu Khola watershed and community-based NGOs, organisations, and district-level government offices (Divisional Irrigation Office and District Soil Conservation Office) had started promoting drip irrigation within and outside the watershed.

How to Reduce Workloads, Especially of Women

The workload for mountain women is higher than for men throughout the year, especially in fetching water, collecting fodder and fuelwood, and household work. In the PARDYP Nepal watersheds, a survey showed that women typically worked 3.8 hours longer per day than men. Various on-farm interventions implemented to generate more income have increased the workload on women. Given that women are also responsible for health and hygiene, childcare, and food security within a household, their greater workload hampers overall livelihood security. Therefore it is important to reduce women's workload for the overall welfare of the family. PARDYP tested roofwater harvesting jars, drip irrigation, and fodder planting activities as ways to reduce women's workload.

Water harvesting jars

Rainwater harvesting has been identified by PARDYP as a potential way of reducing women's workload in fetching water. The potential of roof-water harvesting using ferro-cement jars was demonstrated in both watersheds (See Chapter 3 and Figure 44). PARDYP's 1999 water survey in the Jhikhu Khola watershed indicated that in two-thirds of the households females, including young girls, are responsible for fetching water. People in the Jhikhu Khola spent an average of 33 minutes for each trip (5-120 min) to fetch 1 gagri (15 litre jar) of water (Prajapati et al. 2003). Construction of roof-water harvesting jars reduced this to an average of about 5 minutes (Sharma and Chiranjivi 2001).

Figure 44: Roof-water harvesting jar saves women's time in fetching drinking water

The total time saved in fetching water depends on the type of source, the distance from the source to house, family size, and the flow of water in the source. One analysis indicated that on average 20 sq.m of roof-water harvest saved about 358 hours yearly for a family of 2-4, 528 hours for a family of 5-6, and 591 hours for a family of 7 or more. Doubling the roof area to 40 sq.m saved 418, 674, and 795 hours for fetching water, respectively (see Annex 9). In addition, the use of rainwater during the monsoon season for drinking and other household uses is leading to better health and sanitation.

Grass and fodder species

Over the past few decades, the Jhikhu Khola watershed has witnessed an increase in forest cover due to community forestry programmes, but shortages of fodder and grass remain critical for local residents, especially during the dry season from March to May. PARDYP has been distributing various grass and fodder species to farmers since 2000 to

Figure 45: Fodder development helps women to reduce fodder collection time

help minimise fodder scarcity. About 500 households in the watershed took planting material from the project sources between 2000 and 2003. A survey of 51 randomly selected households was conducted to find out the impact of growing these grasses and to quantify how much workload (especially women's) had been reduced due to this intervention (Figure 45).

The survey found that after growing and harvesting grass from their private land, 35% of the farmers saved 30 to 60 minutes per day in collecting fodder, and 20% saved 60-90 minutes. Most of the women respondents said that they were spending less time collecting forage because the grass species were growing near their homes. They felt that they benefited the most during the busy seasons. Some mentioned that they could cook food and feed livestock at the same time after completing hard work in the field. A few farmers said that their children, also responsible for fodder collection, were getting more time for studies.

Drip irrigation

Due to easy access to the market at Kathmandu, farmers from the Jhikhu Khola watershed have shifted from subsistence to commercial farming and emphasised growing cash crops, mainly vegetables. However, the shortage of water increased the workload of women.

PARDYP, with the collaboration of the Institute of Engineering at Pulchowk, tested and demonstrated drip irrigation (see Chapter 3) in the Jhikhu Khola watershed from 1999 to 2001 with the aim of reducing women's workload by reducing the amount of time they spent collecting water and irrigating the crops. The results were very encouraging and a survey was conducted to assess the impact of drip irrigation on people's livelihoods and on women's workloads. Drip technology saved 50% of the labour required by conventional bucket irrigation.

After implementing drip irrigation, 43% of women found that their workload had decreased, 29% found no change, and 15% didn't know. Around 14% experienced an increase of workload because they had started growing vegetables during the fallow period when they had not done so previously. Men also saved time because of drip technology, and 26% of women mentioned their husbands now helped them to do some household work; 40% of women perceived their self-esteem was enhanced because of drip irrigation as they could grow cash crops on their own.

Lessons Learned and Recommendations

Maintaining and improving soil fertility

On-farm composting

- Covering traditional compost with black plastic and use of EM enhanced the compost formation process and produced well-cooked compost within 45-50 days rather than 4-6 months with the traditional method.
- The moisture requirement for EM is quite significant. This could be a constraint especially when there is water scarcity.

Soil acidification and lime

- In the Jhikhu Khola watershed, soil acidification is associated with acid causing fertilisers (urea and ammonium sulphate).
- Low soil pH (<5) slows the rate of organic decomposition, makes phosphorous unavailable, and leads to aluminium toxicity.
- The benefits of improved carbon and calcium values are outweighed by the decrease of pH when manure made from pine litter is added.

Leachate

- Leaching volume is significantly higher than runoff in rainfed agricultural land, whereas in degraded land it is slightly lower than runoff.
- Nitrate was most leached from the soil, followed by potassium and then phosphate.
- The average leachate of nitrate, phosphate, and potassium is equivalent to the loss of 683 kg/ha of urea, 17 kg/ha of DAP, and 846 kg/ha of murate of potash in rainfed agricultural land, and 70 kg/ha of urea, 2 kg/ha of DAP, and 174 kg/ha of murate of potash from degraded land.

Rehabilitation of degraded land

Rainfed hill terrace improvement

- Levelling terraces, water management, introducing grasses to the risers, and multiple cropping all raise production, making hill terrace improvement attractive to farmers.

Rehabilitation of degraded lands

- Eyebrow pitting is a technological option to improve soil moisture for vegetative growth in reclamation of dry degraded land.

- Planting various grasses and trees, especially leguminous species, is important for the successful reclamation of degraded land.
- Involvement of the beneficiaries, especially women, must be an integral part of managing the natural resource from the beginning.

Increasing farm income

System of Rice Intensification

- The system of Rice Intensification (SRI) increases yield with fewer farm inputs; therefore it is an option to increase farm income.
- Extensive weed growth is the foremost problem at the initial stage of the SRI, adding 50-60% more to the cost of the first weeding.
- Lack of controlled irrigation and drainage is the major constraint for successful SRI.

Approaches to building community capacity

Farmers' priorities for collegial participation

- Trust building is essential for work in rural communities.
- Entry point activities are important for building trust with a community.

Participatory action research

- People's involvement in research builds ownership, which helps in scaling up.
- Participatory action research not only eased scaling up of the technology but also helped orient people's behaviour to research in other areas, which is essential for the long-term improvement of livelihoods.

Reducing workloads

- Roof-water harvesting, fodder development, and drip irrigation are key activities for saving women's working time.

6 ACCESS

Background

Sociocultural norms and practices shape people's ownership rights and access to assets such as land, water, and household property (livestock, income). Different members of the family have different access and responsibilities. Men are often engaged in ploughing fields, whereas women are engaged in collecting and fetching water, fodder, and fuelwood. Apart from sharing almost half of the farm work, women also have household duties. Hence it is necessary to look into men's and women's roles, responsibilities, knowledge, needs, contributions, and rules and regulations governing the natural resources. Several questions were asked regarding the access to and control over assets so that natural resources could be properly managed on an equitable basis. PARDYP carried out studies in the Jhikhu Khola watershed to address these issues.

What are Feasible Local Rules and Practices for Ensuring Equitable Access to Natural Resources?

Some of the rules and practices used by the inhabitants of the watershed were documented through case studies.

Case study: Gaukhureshwor Community Forest

Equitable distribution of resources among different populations and between men and women is essential for the balanced development of a community. Traditionally, different rules and regulations were practised for equitable distribution. One practice in the Jhikhu Khola watershed is 'gola pratha' (lucky draw). This traditional approach has been incorporated into the community forest regulations.

Gaukhureshwor Community Forest is a 21.5 ha mixed forest of *Schima wallichii, Castanopsis indica, Castanopsis tribuloides,* and *Rhododendron arboreum* located in Dhulikhel municipality, Kabhrepalanchowk district. The District Forest Office handed over the forest to the community in July 1992. The forest has users from eight major villages, with about 52 households in total, a population of 302, and an average population density of 16 persons per ha (as of 2004). Brahmins and Chettris are the dominant ethnic groups, providing 67% of the users.

Forest products are distributed on a household basis; each household has to pay NRs 240 annually, or NRs 20 per month. Each year the user committee issues membership cards to each household. The forest user group has an operational plan, which includes descriptions of rules and regulations, to ensure equal benefits and equitable distribution of available forest products to all members, and for forest protection and management. The plan is submitted to the District Forest Office during the forest handover process. The forest user group manages and distributes forest products according to the agreed plan.

In Gaukhureswor, the community forest is opened twice a year for grass collection: two days in Bhadra (mid August - mid September) and two days in Asoj (mid September – mid October). During these days, all members of the user group are allowed to collect one bhari (~30-35 kg) of grass per day free of cost. Only one member from a household is allowed to collect grass. From Mansir to Falgun (mid November to mid February), fuelwood is collected by pruning and thinning, for which the forest is open four days a month. During this time one member can collect one bhari of fuelwood each day for free. All members can collect up to two extra bharis of fuelwood per day, but have to pay NRs 10 for the first bhari and NRs 40 for the second.

To ensure equitable distribution of fuelwood, the user committee has set up a rule of gola pratha (lucky draw). In this system, all wood from pruning is collected in one place and divided into equal bundles (bhari). To ensure reasonable distribution, each bundle is numbered and the number is put in a container. Each member picks a number from the container and receives the corresponding bundle.

From Mangsir to Jestha (mid November to mid May), members are allowed to collect as much dry litter for animal bedding as they can free of cost. Dry litter encourages forest fires, so unlimited collection is allowed on the assumption that its removal will help to reduce fire hazards. No one is allowed to collect timber from the forest, but if a household encounters natural disasters or calamities, a member can buy timber from the forest at a price 40% lower than the local rate. The maximum limit is set at five cubic feet per member. Non timber forest products (NTFPs) like lokta are the main source of income from this forest and are not distributed to the users but collected and sold communally.

One paid guard is appointed for security against illegal use. So far, the members have followed the rules and regulations, and very few members have been penalised. However, if someone cuts a tree illegally, collects fuelwood, damages small plants, or starts a forest fire, they have to pay a penalty decided by the committee based on the scale of damage. If someone cuts grass illegally, they have to pay NRs. 15, 20, and 40 for the first, second, and third offences, respectively. At the fourth offence the forest guard seizes the equipment and materials used for collecting grass. Similarly, if someone's livestock enters into the community forest, they will be charged depending on the animal: NRs 5, 10, and 20 for a goat; NRs 10, 20, and 40 for a cow; and NRs 20, 30, and 60 for a buffalo for the first, second, and third offences, respectively. The users' committee decides the penalty for the fourth offence. The annual income is spent on the guard's salary and establishment and maintenance of a nursery.

Users claim that because of the good understanding, cooperation among the members, and better management, the quality of the forest and availability of forest products has improved over the past 10 years.

Case Study: Juke Irrigation Canals, Jhikhu Khola watershed

Juke canal is a farmer-managed irrigation system that extracts water close to Tamaghat bridge on the right hand side of the Jhikhu Khola. The system benefits 250 households in 13 villages. It serves command areas of about 45 ha of Panchkhal VDC with an average elevation of about 850m. The development of the Juke irrigation system is believed to have been associated with a traditional water mill that existed until 1983. The total length of the canal is 9.3 km, of which the primary canal is 2.7 km, the secondary 3.5 km, and the tertiary 3.1 km. The whole canal is simple earthen type, but 50m was cemented about 20m downstream of the main intake with the support of the SINKLAMA project in 1983.

The command area is divided into two parts: the head-end and tail-end. The cropping intensity of the Juke command area is about 250%. Around 92% of the farmers cultivate three crops per annum; four crops per annum has also been seen at suitable sites. In irrigated khet land, rice-potato-maize is the most common cropping pattern. Many new vegetables like chilli, bitter gourd, and brinjal have been introduced in the last 5 to 10 years. Farmers have also practiced intercropping mustard, sesame, pulses, and beans with wheat or other vegetables for home consumption.

With the intensification of cropping, the demand for irrigation water is increasing. Because of scarcity of water at the source and seepage, the Juke canal cannot supply water simultaneously to all command areas. Users of the head-end irrigate their land before the users from the tail-end. Having water allows farmers from the head-end to cultivate a higher number of crops compared to the tail-end. Regular cleaning of the canal is essential for irrigating the land in the lower strata. Therefore, to irrigate the land, users from the tail-end have to clean the canal regularly, although they only enjoy the irrigation facilities for a limited time. This has been the practice in the past.

To compensate for this disparity, the water user group charges different service fees for the users of the upper and lower end. The principle is that users who have more and easier irrigation facilities will pay more service fees. This rule was formulated by the users themselves in 2004 and has worked smoothly. The service fee for the upper area is set at NRs. 30 per ropani per year, whereas it is only NRs. 20 for the lower area. All the maintenance and cleaning is carried out by the fund raised from the service fees.

Irrigation always starts from the head because of the perception that water from the head will gradually seep downward. If somebody downstream is irrigating, upstream users generally do not divert water. However if someone needs water urgently, with mutual understanding they can share water at the same time. For the winter crop, the majority of tail-end users irrigate their land at night.

Access to Institutions and Information

Social assets

The Livelihood Survey 2005 found that 64% of respondents believe that various non-government and government organisations were working actively in the study area. However, 33% did not believe it and 4% didn't know. Further, 41% of respondents believe that they benefited from these organisations, whereas 57% didn't believe it and about 2% did not know.

Participation in formal organisations

The Livelihood Survey 2005 found that 53% of respondent households had at least one family member participating in a formal organisation[1] such as a women's organisation or credit cooperative. There was no formal political participation among the surveyed households, although 27% of women were participating in women's organisations, followed by 18% in credit co-operatives. Self-help groups, marketing co-operatives, farmers' organisations, and religious and tribal organisations all existed in the study area. Some households were involved in more than one institution.

Political participation

Political participation means using the right of voting in any election. Some 67% of respondents were participating in voting processes. The people in the area were politically active and aware of their political rights. Men and women voted in equal numbers, and participation in national and local level elections was above 50%.

Information

People in the study area gathered information by means of Telivision, radio, newspapers, social gatherings, and informal meetings. Some 85% of households used these means daily, 14% only occasionally, and 1% never. Of the surveyed households, 49% had a television set and 83% a radio, and these were the main sources of information.

Access to Natural Resources

Women responsible for fetching water and fodder

Piped water is the main source of drinking water – 61% of the surveyed households used piped water, of which 41% used public and 20% private water taps. Springs are the second largest source of drinking water (36%) followed by other sources such as dug wells (3%). Two-thirds of the households spent 5 minutes or less for one trip to fetch water, 16% spent 5 to 15 minutes, and 18% more than 15 minutes. The maximum time reported per trip was 90 minutes and the least was 1 minute. In generally, fetching water has been the job of women. Men fetched 32% of total water and women 68%, and 29% of men and 61% of women were involved in the work (Livelihood Survey 2005).

[1] Formal organisation means an organisation formed with a working committee and constitution.

Adoption of on-farm options: grass

There has been a substantial decreasing trend in the availability of grass and shrubs in the Jhikhu Khola watershed over the last three decades. Due to limited access to community forests and small landholding sizes, forage availability is becoming of critical importance for sustaining the agricultural systems in the watershed. In order to address community fodder needs, PARDYP tested and distributed a number of promising fodder and grass/legume species that can be grown inside community forest and land and on private lands belonging to communities or farmers living within or outside the watershed. The species included sunhemp (*Crotalaria juncea*), tephrosia (*Tephrosia candida*), molasses (*Melinis minutiflora*), napier (*Pennisetum purpureum*), flemingia (*Flemingia microphylla*), stylo (*Stylosanthes guianensis*), vetiver (*Vetiveria lawsoni*), dinanath (*Pennisetum pedecellatum*), signal grass (*Brachiaria decumbens*), gini grass (*Panicum maximum*), joint vetch, tithonia (*Tithonia diversifolia*), guatemala (*Tripsacum laxum*), broom grass (*Thysanolaena maxima*), wynn cassia (*Chanaecrista rotundifolia*), kudzu (*Peuraria phaseoloides*), mott napier (*Pennisetum purpureum*), and hemata (*Stylosanthes hamata*). Distribution of potential fodder and grass and legume species to farmers within the watershed was initiated in 2000. A total of 477 kg seeds of different species and 14,570 seedlings or slips were distributed to about 500 farmers, either individually or in groups. PARDYP also built the farmers' capacities by awareness raising through workshops, meetings, study tours to demonstration sites, and training on methods of planting and raising the identified species, and also provided technical backstopping for their needs.

A survey was conducted in May 2004 on the access, status, and adoption of the species distributed; 51 households (about 10% of the total) were randomly selected for the survey. The sampled households represented the south and north aspects of the watershed, valley bottoms, and middle hills of four village development committees (Baluwa, Patalekhet, Hokse, and Panchkhal), and almost all the caste/ethnic groups in the watershed – Brahmin, Chhetri, Tamang, Danuwar, and Newar.

Depending on their needs and interests, the farmers took 1 to 12 species for planting in their private lands. At the time of the survey, about 90% of farmers had sown between one and nine species in their fields (Table 15, Figure 46).

About 94% of the farmers took seeds of sun hemp (*Crotalaria juncea*) and tephrosia (*Tephrosia candida*); and about 77% and 63%, respectively, were growing these species. The two species performed well in terms of survival rates and condition of the plants. Although 30 out of 51 farmers had taken cuttings or seedlings of Napier-NB21 (*Pennisetum purpureum*), only 19 farmers were growing it though the growth was excellent.

Table 15: **Grass species planted**

No of species	0	1	2	3	4	5	6	8	9
Number of farmers adopting	5	4	13	15	7	4	1	1	1

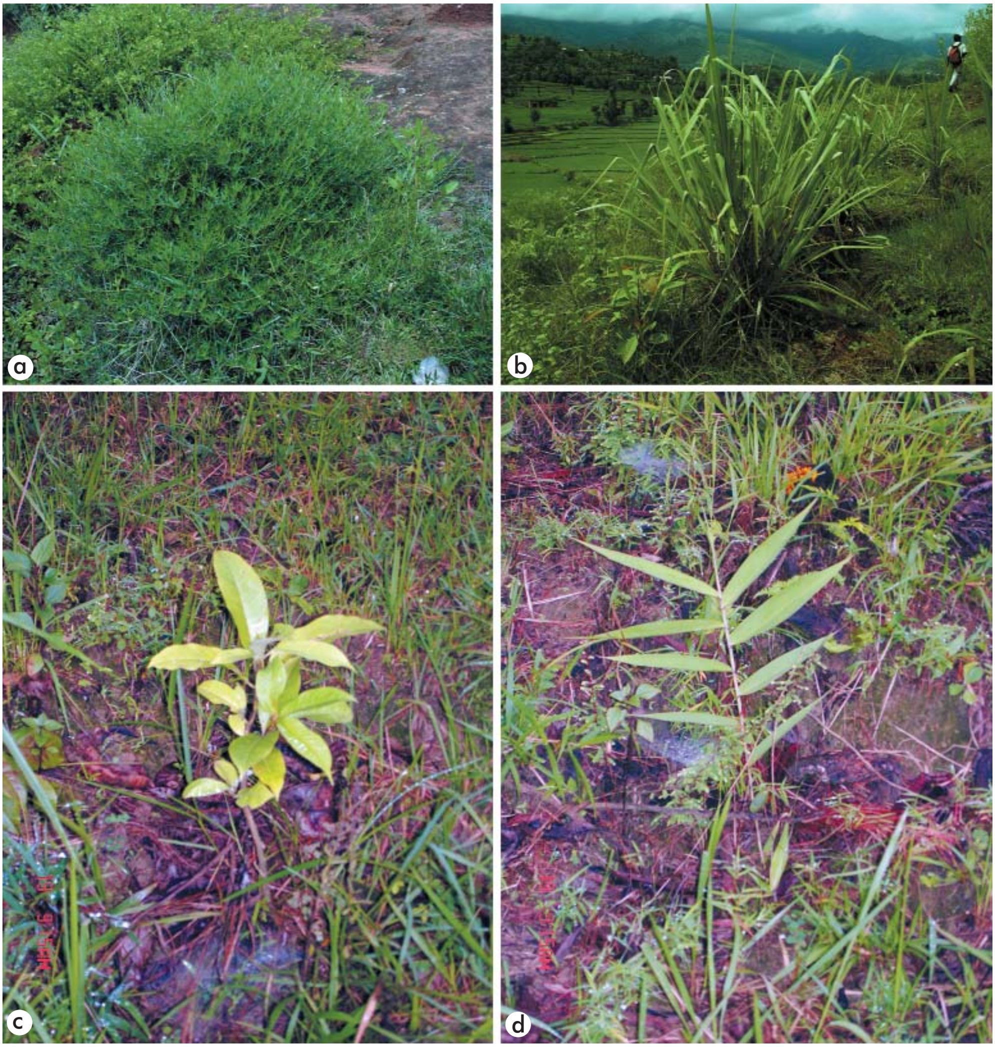


Figure 46. Adoption of different fodder species
a) Stylo (*Stylosanthes guianensis*); b) Guatemala grass (*Tripsacum laxum*);
c) Champ (*Michelia champaca*); d) Amriso (*Thysanolaena maxima*)

Molasses (*Melinis minutiflora*) was distributed to 65% of the sample farmers, of whom 58% were growing it. A few farmers grew molasses mixed with stylo (*Stylosanthes guianensis*). One farmer in Hokse was impressed with molasses and grew it on almost all the riser bunds of his rainfed land; the total row length was more than 1 km.

The survey indicated that 73% of the farmers planted grasses for fodder; 13% for seeds; 7% for stabilisation of the terraces; and 2% for slide control, testing, and beekeeping. Sunhemp and tephrosia can be used as live fences, as stakes for tomato, and as firewood after drying. Molasses is an evergreen grass and stylo makes terrace risers very strong. One farmer planted tithonia for beekeeping purposes. Napier was the preferred grass species, followed by molasses (Figure 47). A few said feeding napier to cattle

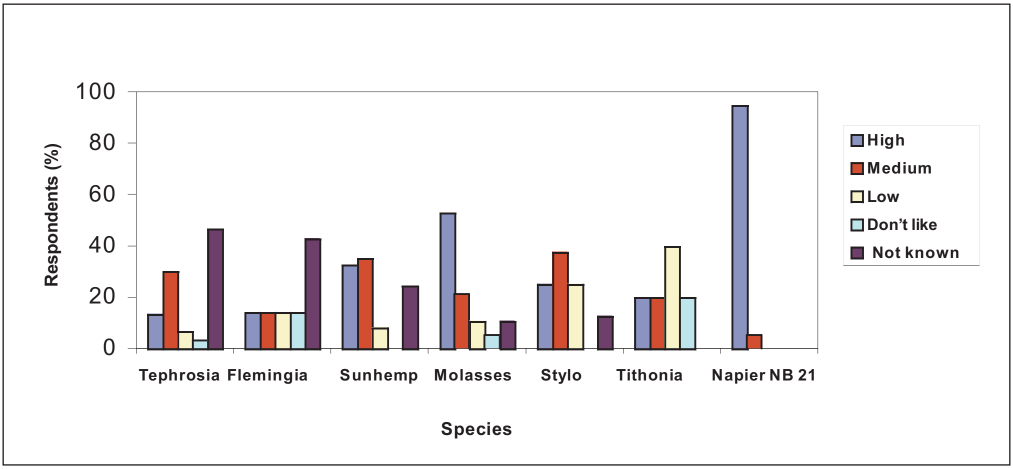


Figure 47: Species preference (ranking)

increased milk production. Napier was introduced a long time ago in the watershed (15-20 years) and is now widespread. Most livestock did not like the smell of molasses in the beginning but eventually started liking it. Stylo, sunhemp, and tephrosia were given second preference.

The grasses were mainly grown along bunds, mostly in single rows. A few species were planted in blocks. Biomass production of some of the grass species was recorded (Table 16).

Among the distributed species, the best performing were sunhemp, tephrosia, napier, and tithonia; molasses, stylo, and guatemala were medium; and dinanath, dignal grass, gini grass, joint vetch, and flemingia were low performing species in terms of survival rates and healthiness.

The farmers preferred species with multiple uses. A few farmers said that stylo and molasses increased milk production in cattle and buffalo and were very good rainy

Table 16: **Biomass estimation from different hedgerow species**

Species	Biomass yield in kg per 100 m		Biomass yield in kg per sq.m
	Range	Average	
Tephrosia	400 to1,200	840	4.6
Flemingia	400 to 600	500	10
Sunhemp	185 to 2,050	825	5 to20
Molasses	60 to 1,500	475	1.5 to 16
Stylo	na	86	2.2 to 16
Napier NB 21	684 to 7,700	3,100	na
Tithonia			16 to 34

na = not available

6 – Access

season forage. Tephrosia and sunhemp were good for winter. However, one farmer explained that due to the shading effect of sunhemp, growth of barley was poor, but later when cut to half its height production became very good.

Due to availability of fodder near their homes, most women were spending less time on fodder collection, and could utilise this saved time for other household work such as cooking, feeding livestock, and looking after their children.

People were collecting seeds and slips for further expansion, and some of them were distributing to their neighbours. The adoption rate was slow, but could increase if projects like PARDYP provide continuous technical support.

Decision-making for Different Activities

There were significant gender differences in decision-making processes. About 40% of women played a role in selling and buying food items in small quantities, and decisions related to livestock, jewellery, and kitchen items (Table 17).

Table 17: **Decision structure by sex**

		Male	Female
Agricultural equipment		72	28
Food items:	small	60	40
	large	71	29
Education		72	28
Land		61	39
Livestock		59	41
Jewellery		53	47
Kitchen		60	40
Other		67	33

In almost all households (99%) at least one member had been out of the village in the past year; 11% of the households had made visits to the NGO office, 52% to a government office; 71% to their relatives; 88% to their parents' households; 93% to the market; and 67% to medical facilities. Around 2% had made visits to other destinations including church, abroad, and school (Table 18). The purpose of individual visits is also shown in Table 18. Only 2.4% of people had visited NGOs, 12.8% had visited government offices, 25.2% markets, 19.6% medical facilities, 39% parents' houses, 28.9% relatives, and less than 1% others. More men visited the NGOs, GOs, market, and relatives than women, but men and women visited medical facilities equally. Women visited parents' houses more than men.

Table 18: **Places visited out of the village**

Visited out of village	By household		By individuals (%)		
	No of HHs	%	Male	Female	Total
NGO Office	18	11	1.4	1.0	2.4
Government office	88	52	11.8	1.0	12.8
Relatives outside village	120	71	16.0	12.9	28.9
Parent's home	148	88	16.6	22.4	39
Market	157	93	16.7	8.5	25.2
Medical facility	113	67	9.8	9.8	19.6
Other (abroad, school)	3	2	0.5	0.4	0.9

Lessons Learned and Recommendations

Local rules and practices

- Indigenous methods such as gola pratha (lucky draw) rooted in community practices are sustainable natural management tools, and need to be explored to promote equitable distribution of benefits.
- Equitable contribution (service fee) and distribution of benefits is a key strategy for sustainable management of community activities.

Adoption of on-farm options

- Activities that can be easily sustained and that fulfil people's daily needs are generally adopted.
- Napier is the most preferred grass species because of its growth and acceptance by livestock.

7 BIBLIOGRAPHY AND FURTHER READING

Bibliography

AICC (2005) *Agriculture Development Diary-2005* Kathmandu: Agriculture Information and Communication Centre, Lalitpur, Ministry of Agriculture and Cooperatives

ATS/CIIFAD (nd) *How to Help Rice Plants to Grow Better and Produce More: Teach Yourself and Others.* Antananarivo (Madagascar): Association Tefy Saina and New York: Cornell International Institute for Food, Agriculture and Development. URL: http://ciifad.cornell.edu/sri/manuals.html

Brown, S. (1999) *Gender and Resources in the Middle Mountains of Nepal*. Vancouver: University of British Columbia, Institute of Resources and Environment

Chitrakar, P.L. (1990) *Planning, Agriculture and Farmers; Strategy for Nepal*. Kathmandu: Kedar Pradhan Printing Support Ltd

Dominique, G.; Gonsalves, J.; Upadhyay, K. (2005) *External Review Report,* Internal Report prepared for People and Resource Dynamics Project. Kathmandu: ICIMOD

Eckholm, E.P. (1976) *Losing Ground. Environmental Stress and World Food Prospectus.* Washington D.C.: Worldwatch Institute

FAO (1998) *Crop Evapotranspiration - Guidelines for Computing Crop Water Requirement*, Irrigation and Drainage Paper 56. Rome: Food and Agriculture Organization

Gole, C.V.; Chitale, S.V. (1966) 'Inland Delta Building Activity of Koshi River.' In *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers*, March 1966

Gupta, G.P. (1975) 'Sediment Production – Status Report on Data Collection and Utilization.' In *Soil Conservation Digest*, 3 (2), September 1975. Dehra Dun: Association of Soil and Water Conservationists and Trainees

HMGN (1975) *Experience of Anti-Desertification Campaigns in Nepal. A Country Paper on Desertification.* Kathmandu: His Majesty's Government of Nepal

ICIMOD (2002a) *Water and Erosion Studies of PARDYP-Nepal: Data of the Jhikhu Khola Watershed*, with updates to 2006. Kathmandu: ICIMOD

ICIMOD (2002b) *Water and Erosion Studies of PARDYP-Nepal: Data of the Yarsha Khola Watershed.* Kathmandu: ICIMOD

ICIMOD (2002c) *Water Demand and Supply Survey*. Kathmandu: ICIMOD

ICIMOD (2002d) *PARDYP in the HKH Region*, CD-ROM. Kathmandu: ICIMOD

Livelihood Survey (2005), unpublished internal report prepared for PARDYP, ICIMOD, Kathmandu

LRMP (1986) *Land Use Map,* Land Resource Mapping Project. Kathmandu: Department of Survey

Mathema P.; Singh, B. K. (2003) *Soil Erosion Studies in Nepal: Results and Implications*. Kathmandu: Department of Soil Conservation and Watershed Management

Merz, J. (2004) *Water Balance, Floods and Sediment Transport in the Hindu Kush-Himalayas: Data Analyses, Modelling and Comparison of Selected Meso-scale Catchments,* Ph.D.Thesis. Berne: University of Berne, Geographica Bernensia and Kathmandu: ICIMOD

Merz, J.; Dangol P.; Dhakal, M. (2000) 'Comparison of Climatological Balances for the Jhikhu Khola and Yarsha Khola Watersheds, Nepal.' In Allen, R.; Schreier, H.; Brown, S.; Shah, P.B. (eds) *The People and Resource Dynamics Project, The First Three Years (1996-1999)*. Kathmandu: ICIMOD

Merz, J.; Nakarmi, G.; Shrestha, S. K.; Dahal, B. M.; Dangol, P. M.; Dhakal, M .P.; Dongol, B. S.; Sharma, S.; Shah, P. B.; Weingartner, R. (2003) 'Water: A Scarce Resource in Rural Watersheds of Nepal's Middle Mountains'. In *Journal of Mountain Research and Development,* 23: 41-49

Merz, J.; Nakarmi, G.; Shrestha, S.; Shrestha, B.; Shah, P.B.; Weingartner, R. (2002) *Water Demand and Supply in Rural Watersheds of the Nepal Middle Mountains: the Local Perception in the Yarsha and Jhikhu Khola Watersheds*. Kathmandu: ICIMOD

Nakarmi, G. (2003) *Executive Summary of Soil Erosion Research Conducted in Jhikhu Khola (1992-2002), and Yarsha Watersheds (1997-2000)*, unpublished paper prepared for PARDYP- Nepal

Nakarmi, G.; Merz, J.; Dhakal, M. (2003) 'Harvesting Roof Water for Livelihood Improvement: A Case Study of the Yarsha Khola Watershed, Eastern Nepal'. In *News Bulletin of Nepal Geological Society,* 20: 83-87

Prajapati, B.; Shah, P. B.; Nakarmi, G.; Shrestha, B.; Merz, J. (2003) '*Initiative Towards Reducing Women's Workload',* unpublished paper prepared for PARDYP-Nepal

Rieger, H.C. (1976) 'Floods and Droughts: The Himalaya and the Ganges Plains as an Ecological System'. In *Mountain Environment and Development*, a collection of papers published on the occasion of the 20th Anniversary of the Swiss Association for Technical Assistance in Nepal (SATA). Kathmandu: SATA

RWSSSP (1994) *Palpa District – Water Supply and Sanitation Development Plan (Draft).* Kathmandu: Department of Water Supply and Sewerage, HMG/Ministry of Housing and Physical Planning

Schreier, H.; Shah, P. B. (2000) 'Soil Fertility Status and Dynamics in the Jhikhu and Yarsha Khola Watersheds'. In Allen, R.; Schreier, H.; Brown, S.; Shah, P.B. (eds) *The People and Resource Dynamics Project, The First Three Years (1996-1999).* Kathmandu: ICIMOD

SCWMC (2004) *Soil Conservation and Watershed Management Measures and Low Cost Techniques*. Kathmandu: Soil Conservation and Watershed Management Component-Department of Soil Conservation and Watershed Management

Shah, P.B. (2003) 'Nutrient Dynamics in Farming Systems of Jhikhu Khola Watershed' In White, R.; Bhuchar, S.K. (eds) *Resource Constraints and Management Options in Mountain Watersheds of the Himalaya.* Kathmandu: ICIMOD

Sharma, C. (2001) *Socioeconomic Indicative Impact Assessment and Benchmark Study on Rooftop Rainwater Harvesting Kavre Palanchok District, Nepal*, unpublished paper prepared for ICIMOD

Sherchan, K.K.; Banyia, B.K. (1991) 'Crop Production and its Trend in Response to Soil and Nutrients'. In Shah, P.B.; Schreier, H.; Brown, S.; Riley, W.K. (eds) *Soil Fertility and Erosion Issues in the Middle Mountains of Nepal.* Ottawa: International Development Research Centre

Shrestha, B. (1999) 'Population Dynamics and Land Use in the Yarsha Khola Watershed.' In Allen, R.; Schreier, H.; Brown, S.; Shah, P.B. (eds) *The People and Resource Dynamics Project, The First Three Years (1996-1999)*. Kathmandu: ICIMOD

Shrestha, B. (2005a) *Population Dynamics in the Jhikhu Khola Watershed*, unpublished paper prepared for PARDYP-Nepal

Shrestha, B. (2005b) *Land Use Dynamics and Agricultural Intensification in the Jhikhu Khola Watershed*, unpublished paper prepared for PARDYP-Nepal

Shrestha, B. Land Use Mapping and GIS, unpublished report prepared for PARDYP-Nepal

Sinclair, T. R. (2004) 'Agronomic UFOs Waste Valuable Scientific Resources'. In *Rice Today,* 3(3):43

Sterling, C. (1976) 'Nepal'. In *The Atlantic Magazine*, USA

Sthapit, K. M.; Balla, M. K. (1998) *Review of Runoff and Soil Loss Studies. A Teaching Material for Soil Conservation and Watershed Management for B.Sc. Forestry.* Pokhara: Training and Manpower Development in Community Forestry Management Project, Institute of Forestry / International Tropical Timber Organization

Sthapit, K.M. (1996) *Sedimentation Monitoring of Kulekhani Reservoir.* Paper presented at the International Conference on Reservoir Sedimentation, held September 9 - 13, 1996, Fort Collins, Colorado, USA

Suwal, M.; Subedi, K.; Gurung, G. (1991) 'Soil Fertility Thrust Towards Sustainable Agriculture: Experiences of Lumle Regional Agricultural Research Centre'. In Shah, P.B.; Schreier, H.; Brown, S.; Riley, K. (eds) *Soil Fertility and Erosion Issues in the Middle Mountains of Nepal*, pp.61-82. Ottawa: International Development Research Centre

Uphoff, N. (2004) 'System of Rice Intensification Responds to 21st Century Needs'. In *Rice Today,* 3 (3):42

WHO (1997) *Guidelines for Drinking Water Quality. Volume 1: Recommendations,* Second Edition. Geneva: World Health Organization

Further reading

PARDYP has prepared many documents and publications. Some of the publications related to this report are listed below; they are available in the ICIMOD library.

CD-ROMs

Brown, S. (1999) *Gender and Resources in the Middle Mountains of Nepal, Yarsha Khola Watershed*. Vancouver: University of British Columbia, Institute for Resource and Environment

Brown, S. et al. (2002) *Yarsha Khola Watershed, Nepal.* Vancouver: University of British Columbia, Institute for Resource and Environment

ICIMOD (2002a) *Water and Erosion Studies of PARDYP Nepal: Data of the Jhikhu Khola Watershed*, with updates to 2006. Kathmandu: ICIMOD

ICIMOD (2002b) *Water and Erosion Studies of PARDYP Nepal: Data of the Yarsha Khola Watershed.* Kathmandu: ICIMOD

ICIMOD (2002c) *Water Demand and Supply Survey*. Kathmandu: ICIMOD

ICIMOD (2002d) *PARDYP in the HKH Region*, CD-ROM. Kathmandu: ICIMOD

Livelihood Survey (2005), unpublished internal report prepared for PARDYP, ICIMOD, Kathmandu

Schreier, H. et al. (2002) *Jhikhu Khola Watershed, Nepal.* Vancouver: University of British Columbia, Institute for Resource and Environment

Shah, P.B.; Shrestha, B.; Nakarmi, G; Allen. R. (1997) *Complex problems - complex options: preservation, degradation and rehabilitation in a Nepalese Watershed, PARDYP Project on People and Resource Dynamics in the Himalayas*. Vancouver: University of British Columbia, Institute for Resources and Environment

Theses

Brown, S. (1997) *Soil Fertility, Nutrient Dynamics and Socioeconomic Interactions in the Middle Mountains of Nepal,* Ph.D.Thesis. Vancouver: University of British Columbia, Institute for Resources and Environment

Merz, J. (2004) *Water Balance, Floods and Sediment Transport in the Hindu Kush-Himalayas: Data Analyses, Modelling and Comparison of Selected Meso-scale Catchments,* Ph.D.Thesis. Berne: University of Berne, Geographica Bernensia and Kathmandu: ICIMOD

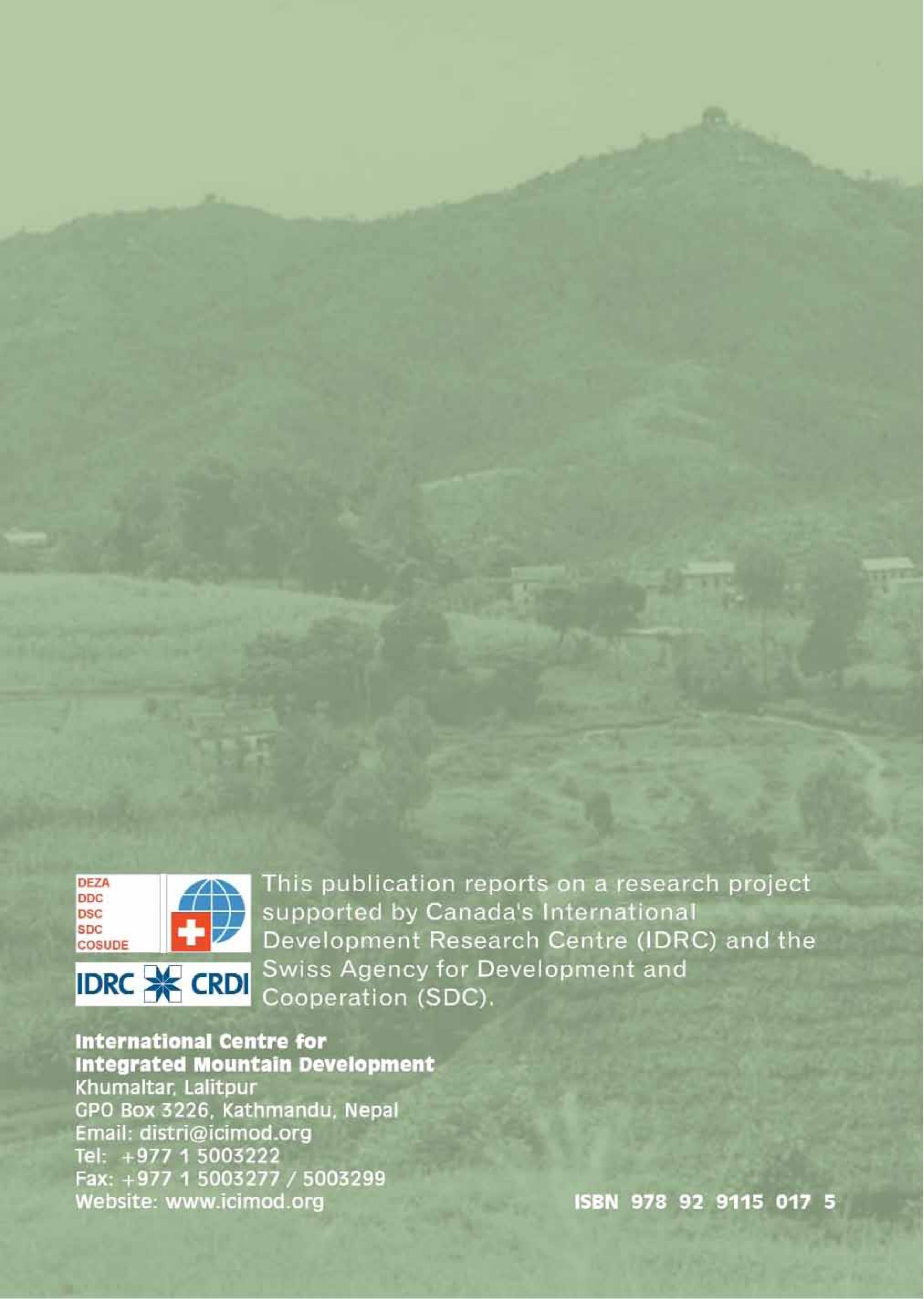
Schaffner, M. (2003) *Drinking Water Quality Assessment and Improvement in the Jhikhu Khola Catchment, Nepal,* Master's Thesis. Berne: University of Berne

Von Westarp, S. (2002) *Agricultural Intensification, Soil Fertility Dynamics, and Low Cost Drip Irrigation in the Middle Mountains of Nepal,* Master's Thesis. Vancouver: University of British Columbia, Institute for Resources and Environment

Proceedings

Allen, R.; Schreier, H.; Brown, S.; Shah, P.B. (eds) (2000) *The People and Resource Dynamics Project, The First Three Years (1996-1999)*. Kathmandu: ICIMOD

White, R.; Bhuchar, S.K. (eds) (2005) *Resource Constraints and Management Options in Mountain Watersheds of the Himalaya.* Kathmandu: ICIMOD



DEZA DDC DSC SDC COSUDE

IDRC CRDI

This publication reports on a research project supported by Canada's International Development Research Centre (IDRC) and the Swiss Agency for Development and Cooperation (SDC).

International Centre for Integrated Mountain Development
Khumaltar, Lalitpur
GPO Box 3226, Kathmandu, Nepal
Email: distri@icimod.org
Tel: +977 1 5003222
Fax: +977 1 5003277 / 5003299
Website: www.icimod.org

ISBN 978 92 9115 017 5