Session V

Promoting Decreased Physical Vulnerability within Watersheds and Regional River Basins

Emerging Options in Watershed Management: Lessons Learned in PARDYP

Roger White, Regional Programme Coordinator/ Watershed Management, Natural Resources Management Programme and **Sanjeev K. Bhuchar,** Watershed Coordinator, People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project, International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal

Introduction

Farmers in the middle mountain watersheds of the Hindu Kush-Himalayan (HKH) region are generally smallholders with typically less than one hectare of cropping land per household. The majority of them do not have proper access to irrigation and rely on rainfall, which is distinctly seasonal. In the irrigated valley bottoms, agriculture is becoming intensified and commercialised. In places along the roads, traditional rainfed farming is also gradually shifting towards the cultivation of seasonal cash crops, but by and large it is still oriented towards subsistence, labour intensive, and nonprofitable. Studies in the ICIMOD-coordinated 'People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas' Project (PARDYP: Box 1, Figure 1) show that more than 50% of the farmers surveyed in the PARDYP-India watersheds did not consider agriculture sufficiently profitable, which in effect was putting many young farmers off their fields (PARDYP Livelihood Survey 2005).

Transformation of subsistence mountain agriculture into an enterprise that is ecologically beneficial and economically attractive to support the livelihoods of upland farmers has been an uphill task. Action research in PARDYP showed that it is possible to bring about such transformation if a) farmers' capacities and skills to address the core issues of water management, soil fertility management, and degraded land management are improved; b) market linkages are addressed; and c) dissemination of knowledge is improved. But before embarking on such initiatives it is equally important that the environmental and socioeconomic context in which farmers live are properly understood. This paper presents some of the main PARDYP findings and results including popular on-farm options which have caught the imagination of farmers and extension workers within and outside the PARDYP watersheds (Figure 1).

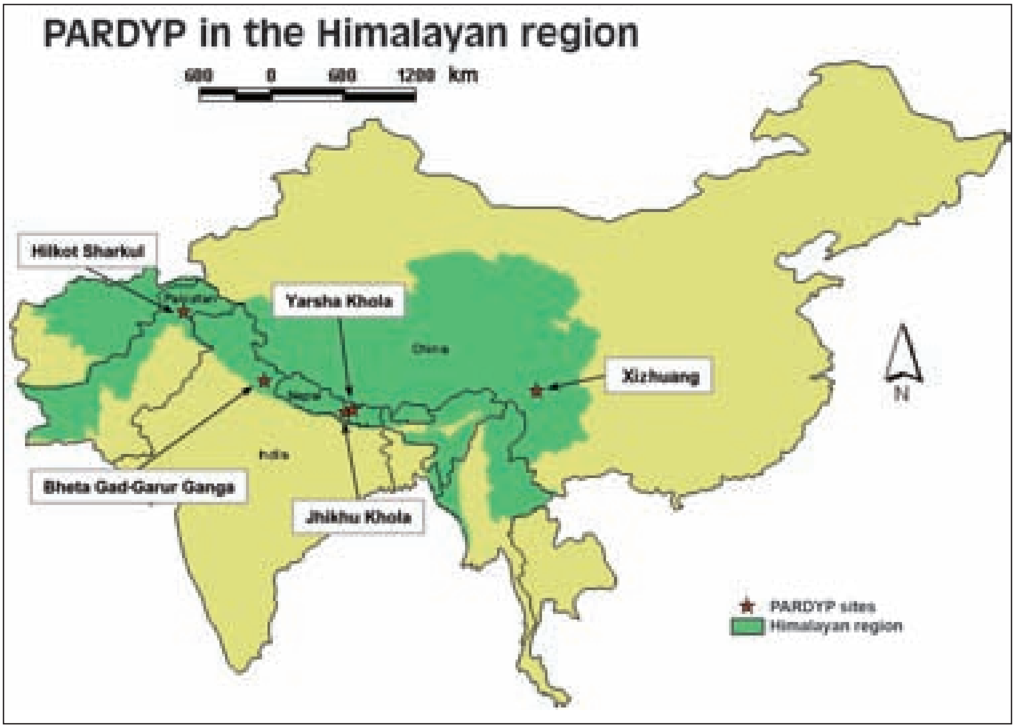

Figure 1: Location of PARDYP watersheds

Key findings and results

Water quantity and quality

PARDYP collected data and information on hydrology and meteorology of its study areas for about nine years. The resulting data sets provide a long-term baseline against which the impact of changes in land use and land management on water quality and quantity can be measured. In addition, PARDYP has drawn together data from the watersheds to analyse parameters such as soil erosion, rainfall intensity, high and low flows, and water quality. All these have been described in detail in various PARDYP publications. The key ones are Merz (2004), Merz et al. (2005), and Dangol et al. (2005). The main messages that emerge out of the analysis are as follows.

- Adequate water is available in the middle catchments to meet human and livestock needs provided water resources are properly and adequately managed. For example, the intensively cultivated Jhikhu Khola watershed in Nepal receives a total annual precipitation of about 1295 mm. Of this, 869 mm is lost through ‘beneficial for the crop’ evapotranspiration and 411 mm flows out of the watershed as runoff, mostly during the monsoon season (Merz 2005).

Box 1: **PARDYP worked with research institutions and local communities in the following fields.**

- Research in hydrology and meteorology
- Soil erosion and fertility studies
- Participatory conservation activities
- Agronomic and horticultural initiatives
- Socioeconomic and access studies

PARDYP was funded by the Swiss Agency for Development and Cooperation (SDC), International Development Research Centre (IDRC), and ICIMOD.

- Well-managed farm land has very low soil erosion rates (less than 5 t/ha) and thus does not warrant major efforts towards soil conservation per se. Methods that lead to better land husbandry and result in savings and income for farmers are needed.
- Drainage, road networks, severely degraded areas, and steep sloping agricultural lands are major sources of sediment and need effective sediment control measures.
- Spring and river sources in PARDYP watersheds suffer from problems with drinking water quality. Water quality studies in PARDYP found faecal coliform contamination in most spring sources in all watersheds far above the World Health Organisation (WHO) limits.
- An important problem that PARDYP has identified is the amount of nutrients leaching from soils in farmers' fields. This seems to be significant and can have a big impact on farmers' costs and groundwater quality. Studies in PARDYP Nepal show that the average leachate of nitrate, phosphate, and potassium is equivalent to the loss of 683 kg/ha of urea, 17 kg/ha of diammonium phosphate (DAP), and 846 kg/ha of murate of potash from rainfed agricultural land.

Table 1: The PARDYP watersheds and their characteristics

Physiography	Xi Zhuang (China)	Bheta Gad Garur Ganga (India)	Jhikhu Khola (Nepal)	Yarsha Khola (Nepal)	Hilkot-Sharkul (Pakistan)
Total area (ha)	3,456	8,481	11,141	5,338	5,230
Elevation Range (m)	1,700-3,075	1,090-2,520	800-2,200	1,000-3,030	1,448-2,911
Climate	Wet and dry seasonal variation	Sharp wet and dry seasonal variation	Humid sub-tropical to warm temperature	Humid sub-tropical to warm temperature	Humid sub-tropical to cool temperatures
Dominant geology	Limestone and sandstone	Schists and gneiss	Mica schist and limestone	Gneiss and slate+graphitc schist	Micaceous schist, slates,
Total population	4,016 (1997)	14,524 (1998)	48,728 (1996)	20,620 (1996)	11,322 (1998)
Population density (people/sq.km)	116 (128 in 2002)	171	437 (587 in 2001)	386	243
Family size	4	7	6	5	8
Dominant ethnicity	Han, Chinese	Brahmin, Rajputs, Scheduled castes	Brahmin, Chettri, Tamang, Danuwar	Brahmin, Chettri, Tamang	Gujar, Swati, Syeds
Major cash crops	Tea tobacco fruits	Winter vegetables fruits tea, fodder	Potatoes tomatoes rice, fruits vegetables	Seed potatoes some fruits	Fruits fodder
Main staple crops	Maize wheat beans potatoes rice	Mixed cereal grains rice wheat	Rice maize wheat potatoes millet	Maize rice millet potatoes wheat	Wheat maize rice

Water management

For improved water management PARDYP recommends the following measures.

- Protecting spring sources, promoting local management rules by strengthening groups, and planting species (e.g., vetiver) to filter overland flow (Figure 2)
- Treating water at the household level through solar disinfection (SODIS) methods using discarded plastic water bottles and treating with chlorine where contamination remains
- Installing mud-lined or plastic-lined ponds to harvest rainwater and perennial water sources
- Installing 500-1000 litre tanks to harvest rainwater from roofs for domestic supplies throughout and following monsoon
- Installing simple, locally available, cheap drip irrigation sets (with or without plastic mulches) to cut the amount of water needed to grow some crops by up to 60%.

PARDYP Nepal

Figure 2: **Community-based rehabilitation with rules for proper management of Dhotra springs in Nepal has led to increased drinking water security for spring users**

On-farm and common property research

Through participatory action research, PARDYP has identified sustainable farming practices that reduce environmental impacts and increase farmers' incomes and livelihoods without increasing women's workloads. PARDYP's research found the following options promising for farmers in the HKH region.

Incorporating legumes in farming

Legumes are plants that fix nitrogen in the soil naturally. In Pakistan, maize with intercropped legumes yielded between Pakistani rupees (PR) 2,100 and 9,600/ha of increased income from better production. Peas, a legume crop, when grown with onions, also yields significant increases in income (Table 2).

Table 2: Comparison of onion and pea yields when grown alone and intercropped			
Treatments	Yield (kg/12m^2)	Yield (t/ha)	Income (PR/ha)
Onions alone	15 (onions)	12,500	100,000
Peas alone	7 (peas)	5,833	145,825
Onions+peas	13 (onions) + 5 (peas)	10,800 (onions) + 4166 (peas)	86,400 (onions) + 104,150 (peas)
Source: PARDYP Pakistan (1 USD=approx. 58 Pakistani Rupees)			

Improved rainfed hill terrace *(local name in Nepal,'Gara-kanla sudhar')*

This technology is a combination of mechanical and vegetative measures. Sloping land is converted into level terraces and hedgerow species are planted along the margins (Figure 3). The species popular in Nepal are Napier *(Pennisetum purpureum)*, molasses *(Melinis minutiflora)*, stylo *(Stylosanthes guianensis)*, sun hemp *(Crotalaria juncea)*, tephrosia *(Tephrosia candida)*, and flemingia *(Flemingia macrophylla)*.

The key benefits of the technology are as follows.

- Less soil erosion, rill erosion, and nutrient leaching compared to sloping agricultural land
- Increase in soil water retention because of reduced slope
- Increase in crop production and fodder and grass availability, thus reducing women's workloads

Figure 3: **Grasses planted during improvement of rainfed hill terrace**

Improved variety of seeds

Hill research institutes in the Himalayas mandated to improve mountain agriculture have produced several improved varieties of crops, most of which have not been tested under real conditions. PARDYP tested a few improved varieties of wheat, peas, maize, and rice with farmers and provided an alternative livelihood option. Many of the farmer participants adopted the tested varieties for increased production (Table 3).

Table 3: Some high-yielding varieties introduced in PARDYP watersheds				
Country	Improved crops	Variety	% Change in yield over local variety	Maturation day
India	Wheat	VL-738	+92-100%	175-180
		VL-616,	+120-125%	210-220
	Peas	Azad-p1	+40 - 60%	115-120
Nepal	Maize	Bio-seed	+100 - 150%	105-110
	Paddy	Pant-10	+80-90%	120-125
Pakistan	Wheat	Suleman-96	+90-110%	191-198
		Inqilab-91	+100-140%	187-192
	Paddy	JP-5	+100-110%	140-150
		Swat-I	+80-90%	118-130

Figure 4: **Conservation pond integrated with farming**

Fish farming

Another success story in PARDYP has been with fish ponds (Figure 4).

In the PARDYP India watershed, a water-harvesting pond fed by perennial water sources for irrigating vegetables has been developed and spontaneously adopted by many farmers. There are 70 fishponds in this watershed which raise three varieties of carp: grass carp, common carp, and silver carp (Table 4). In 2005, farmers sold fish worth Indian rupees (IRs) 144,500 and earned good profits.

Table 4: Characteristics of different fish varieties introduced by PARDYP India			
Items	Common carp	Silver carp	Grass carp
Habitat	Bottom feeder	Surface feeder	Column feeder
Habit	Omnivorous	Planktophagous	Herbivorous
Maturity time	One year	2-3 years	2-3 years
Growth/year (gm)	600-750	750-1000	1000-1500
Source:PARDYP India			

Biofertilisers

Trials in India, Pakistan, Nepal, and China have shown that the application of certain micro-organisms has consistently increased yields by about 20% (Table 5).

Table 5: Effect of Azotobacter chroococcum strains on different crop varieties, local and improved

Crop (variety)	Strain	Yield increase
Wheat (Local; VL-616; VL-738)	W_5	11–18%
Madua (Local; Vl-149)	A_{41}	38-43%
Maize (Local, popcorn)	M_4	21-28%
Tomato, capsicum, aubergine, pumpkin	W_5	16-27%
Source:PARDYP India		

Drip irrigation

In areas where water is scarce, the use of locally available and inexpensive drip irrigation systems enables farmers to grow off-season vegetable crops (Figure 5). Trials in PARDYP-Nepal showed that bitter gourd grown in clay soil (area ~ 150 m2) required 9,800 litres; loam and sandy loam soil required 60% and 80% more water, respectively than clay soil. About 80- 95% of the water was applied from mid-February to May, and the rest (5-20%) was applied occasionally during the dry spells from June to early July in all soil types. Drips saved about 60% of water compared to bucket irrigation without reducing yield in all soil types. Bitter gourd planted on the same day in the same location in (~ 80 m2) in drip and bucket irrigated plots gave the following results.

a) The first harvest came 22 days earlier in the drip plot.
b) Early production yielded better prices and bitter gourd was sold at a higher price.
c) Extra production from the drip plot was 38 kg (equivalent ~NRs 1,000).

Drip irrigation saves about 60% of water compared to bucket irrigation without reducing yields in all soil types. It also helps the crop to mature earlier. In the case of bitter gourd, it was harvested three weeks earlier than the same crops in a plot under bucket irrigation. This helps farmers to sell the product for higher prices. A survey result showed that drip technology saves 50% of the labour force compared to the conventional method using bucket irrigation. Considering efficiency, about 100 farmers in the watershed have adopted drip irrigation for cash crop cultivation.

PARDYP Nepal

Figure 5: **Drip irrigation system**

Improved composting

Vermicomposting (Table 6) was found to be a good option. In the PARDYP-China watershed, vermicompost was tested on tea and maize crops and a 5.7% yield increase for maize and 15.6% for tea crop were reported (Bisht et al. 2005).

Significant improvements in the quality (10%) and rates of composting (40% faster) by covering compost heaps with black plastic sheets have been demonstrated in Nepal, and this method is proving to be popular.

Table 6: Cost-benefit analysis of cultivating tomato and capsicum using vermi-compost and under traditional farmyard manure (FYM) in Rs (Area=0.1 hectare)

Input sectors	Vermicompost		Traditional FYM	
	Tomato	Capsicum	Tomatoes	Capsicum
Seedling costs	444	444	444	444
Vermicompost costs	888	888	532	532
Field preparation	300	300	300	300
Labour costs: irrigation	1,485	1,485	1,485	1,485
Labour costs: weeding	450	540	630	720
Total input	3,567	3,657	3,391.80	3,481.80
Output	18,648	19,536	11,490	11,988
Gross profit	15,081	15,879	7,833	8,507

Values are in Indian rupees: 1 USD = Rs (Indian) 43
Source: PARDYP India

System of rice intensification

Rice farmers can increase their yields by up to 50% by adopting aspects of a system of rice intensification (SRI). This encouraging result has doubled the number of SRI tillers over traditional practices in farmers' trials in the Pakistan and Nepal watersheds (Table 7).

Table 7: Comparative performance of varieties of rice using the traditional method (TM) and a system of rice intensification (SRI) in the PARDYP Nepal watershed

Location	Year	Variety	Grain yield (t/ha, fresh weight)			Straw yield (t/ha, dry weight)		
			TM	SRI	% increase	SRI	TM	% increase
SCDC	2002	Makwanpur 1	8.25	10	21	13.7	13.7	0
SCDC	2003	Makwanpur 1	7.9	10.1	28	9.7	10.8	11
SCDC	2004	Makwanpur 1	7	8.6	23	9	11.8	31
Farmer's field	2003	Makwanpur 1	8	10.5	31	9.1	12.8	41
Farmer's field	2004	Parwanipur	5.5	8	45	5.5	8.5	55
Farmer's field	2004	Japanese mansuli	3	5	67	7.5	7	-7

SCDC:Spice Crop Development Centre (SCDC) in Panchkhal, Jhikhu Khola, Nepal
Source: PARDYP Nepal

Off-season vegetables

PARDYP has been helping farmers in the commercial production of off-season vegetables. In India particularly, off-season vegetable production using simple polyhouse technology (Figure 6) has become one of the most popular activities.


PARDYP Nepal

Figure 6: **A simple polyhouse technology has transformed the life of a poor farmer, Girish Tewari, in the PARDYP India watershed. He now earns about Indian rupees 30,000/0.1 hectare each year by selling seedlings and vegetables**

Rehabilitation of common property resources

Degradation of common property resources in the Himalayas increases the economic, social, and environmental vulnerability of small farmers and poor households. Therefore, it is important for societies and especially vulnerable mountain communities to ensure sustainable management of the mountain commons. PARDYP research focused on understanding the processes of natural resource degradation in the middle mountains of the Himalayas. Initial baseline surveys of the watersheds helped PARDYP to understand the major socioeconomic and biophysical constraints to sustainable crop production and improved livelihoods. This understanding provided the opening to explore sustainable use of natural resources including common property resources (CPRs). PARDYP examples include rehabilitation of degraded community forests in Nepal, and degraded village common lands developed into fodder banks in India. PARDYP also assisted local communities in developing water management options because water scarcity in the dry season was becoming another problem in the middle mountains as increasing demands are exceeding the supply. In all cases, understanding the people dimension was of far greater importance than the technical solutions. It was realised that if communities were aware of the possibilities and given the confidence to develop their ideas, they could improve and manage resources effectively.

Based on these findings and building on existing knowledge, PARDYP has developed technological and approach options for rehabilitating degraded lands. The lessons learned are summarised and presented in this section.

Measures for gully plugging

Gully stabilisation has been an important strategy for rehabilitating badly degraded land in all of PARDYP's watershed sites. PARDYP and its predecessor projects have found that Agave americana, *Dendrocalamus strictus/hamiltonii, Thysanolaena maxima, Pennisetum purpureum,* and *Vitex negundo* are promising bio-engineering species for gully plugging. On more shady and less compacted soils, the establishment of nitrogen-fixing trees such as Alnus nepalensis, in combination with any of the above-mentioned species, shades surrounding areas, reduces moisture loss, and encourages natural regeneration. Where vegetative measures alone are not enough to stem degradation i) checkdams made from soil-filled bags or stones should be built and planted on; (ii) planting trees on the sides of small gullies helps conserve moisture and facilitates grass growth; and iii) digging diversion drains stabilised by planting hedgerow species on their sides can reduce the amount of topsoil washed into gullies; this also means runoff water can be harvested (for example, by building earth-filled dams near the outlet of these drains and in other places).

Vegetative measures for degraded slopes

The following measures have proved successful for rehabilitating degraded slopes.

- Establishing contour lines of hedgerow species, preferably nitrogen-fixing species (Box 2) on exposed and bare sloping areas
- Planting a mix of some tree and shrub species listed in Box 2 alternately at one metre intervals throughout degraded areas

Box 3 enumerates some species recommended for planting on slopes.

Box 2: **Recommended species for planting on contour lines**	Box 3: **Recommended species for planting on slopes**
Flemingia macrophylla, Desmodium intortum, Tephrosia candida, Leucaena diversifolia, Crotolaria juncea, Indigofera species, Stylosanthes hamata, Melinis minutiflora, Vetiveria zizanoides, Sorghum alum, Pennisetum orientale, Thysanolaena maxima, Medicago sativa, Amorpha fructicosa, Pennisetum purpureum (NB 21), *Cajanus cajan, Agave americana, Cotoneaster spp, Ficus tikoua, Mucella laciocarpa, Pueraria lobata, Vitex negundo,* and *Sorghum alum.*	*Cassia siamea, Diospyros kaki, Phyllanthus emblica, Punica granatum, Zanthoxyllum bungeanum, Betula alnoides, Camptotheca acuminata, Melia azedarach, Schima wallichii, Toona ciliata, Toona sinensis, Trachycarpus fortunei, Trema orientalis, Acacia richii, Albizia mollis, Atylosia scarabaeoides, Bauhinia variegata, Bauhinia faberi, Caesalpinia decapetala, Albizia lebbeck, Robinia pseudoacacia,* and *Ailanthus alticima.* (*Dalbergia sissoo* often suffers from die-back problem at maturity in Nepal and is no longer considered suitable for large-scale planting.)

Encouraging the natural regeneration of vegetation on degraded sites

Planting tree species at intervals of at least one metre to avoid too much competition between plants for water and nutrients is a good method for degraded sites. It is better to plant at least one-year old saplings grown inside nursery bags. In PARDYP-India planting in 0.5 cubic metre pits and adding farmyard manure or humus-rich forest soil is recommended.

Another method is to make contour ditches or eyebrow 'terraces' or pits to help harvest surface runoff conserve soil and increase the infiltration potential of land. Materials planted along the bunds of these terraces have a better chance of survival and good growth rates are achieved as they exploit water from the pits. Eventually the pits become filled with eroded soil.

PARDYP experience shows that some of the following factors govern the sustainable development of common resources.

- Community empowerment - Sustainability of rehabilitation work depends on the extent to which local people have been empowered, both socially and technically.
- Organising village campaigns to raise awareness about the benefits of common property resources and explaining the complementarity between CPRs and private resources; applying people-led research and development approaches; motivating village leadership and institutions; reviving traditional institutions; and incorporating traditional knowledge and experiences are some ways in which communities can be better educated and empowered. Marginalised groups and women must be actively involved.
- CPR - private property resource (PPR) complementarity: Farmers in the PARDYP watersheds participated in the conservation and protection of CPRs because of the CPRs' contribution to private resource-based improved options. Providing poor farmers with alternative options that raise the productivity of private property resources is important.

Conclusions

PARDYP's research findings have found the following.

1. There are many good options for farmers and farmers need to be made aware of them. Working with farmers to develop ideas can be rewarding and can lead to good results.
2. New and unexpected problems keep arising in farmers' fields (e.g., nutrient deficiencies resulting from more intensive cropping) and watershed management programmes should be prepared to make adaptations accordingly.
3. In the PARDYP watersheds, which represent about 11% of middle mountain watersheds in the HKH, the important hydrological issue is the low flows in water courses during the dry season. How to improve water management, rather than floods, and how to reduce peak flows are the new challenges.
4. Rates of soil erosion and runoff from agricultural lands are much lower than originally thought and farmers upstream cannot be blamed for floods downstream.

The on-farm options presented in this paper are promising for mountain farmers. PARDYP's extensive research on hydrometeorology gives insights into the water dynamics in middle mountain watersheds where water scarcity and poor water quality are becoming serious problems. Researchers, development workers, and decision makers who are trying to build sound programmes and policies for improved livelihoods of the Himalayan people and for markets for watershed protection services can certainly benefit from the knowledge generated by PARDYP.

Acknowledgements

This paper is a short summary of the work carried out by PARDYP's India, Nepal, China, and Pakistan teams with support from the universities of Berne and Zurich (Switzerland) and British Columbia (Canada) and their research institutions, namely, the Kunming Institute of Botany and Centre for Biodiversity and Indigenous Knowledge in China, G.B. Pant Institute of Himalayan Environment and Development (India), Pakistan Forestry Institute (Peshawar, Pakistan) and ICIMOD (Nepal). We acknowledged all of these institutions and teams for their contributions to generating this valuable information through the PARDYP Project.

Bibliography

Bhuchar, S.K.; Shah, P. B.; White, R. (2005) 'Potential Strategies for Rehabilitating Degraded Lands in the Middle Mountains of the Hindu Kush-Himalayas.' In White, R.; Bhuchar, S.K. (eds) *Resource Constraints and Management Options in Mountain Watersheds of the Himalayas.* Proceedings of of the PARDYP regional workshop, 8-9 December 2003. Kathmandu: ICIMOD

Bisht, S. S.; Kothyari, B.P.; Bisht, B.S.; Mishra, A.K.; Bhuchar, S.K. (2005) 'Consolidation of Farming Options Developed in Earlier Phases of PARDYP.' In White, R.; Bhuchar, S.K. (eds) *Resource Constraints and Management Options in Mountain Watersheds of the Himalayas.* Proceedings of the PARDYP regional workshop, 8-9 December 2003. Kathmandu: ICIMOD

Dangol, P.; Dongol, B.; Dhakal, M.; Merz, J.; Jehangir, M.; Zokaib, S; Verma, P.K.; Joshi, B.; Ma, X.; Fu, G. (2005). 'Water Resources Dynamics: A Comparison of Five Watersheds in the Hindu Kush-Himalayas.' In White, R.; Bhuchar, S.K. (eds) *Resource Constraints and Management Options in Mountain Watersheds of the Himalayas.* Proceedings of of the PARDYP regional workshop, 8-9 December 2003. Kathmandu: ICIMOD

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

Merz, J. (2004) *Water Balances, Floods and Sediment Transport in the Hindu Kush-Himalayas.* Kathmandu: ICIMOD

Merz. J.; Weingartner, R.; Dangol, P.; Dhakal, M.; Dongol, B.S.; Nakarmi, G. (2005), 'Challenges in Water Management in Intensively Used Catchments in the Himalayan Region.' In White, R.; Bhuchar, S.K. (eds) *Resource Constraints and Management Options in Mountain Watersheds of the Himalayas.* Proceedings of the PARDYP regional workshop, 8-9 December 2003. Kathmandu: ICIMOD

White, R. (2005) 'Overview of 'PARDYP Research: Promising Approaches to Watershed Management.' In White, R.; Bhuchar, S.K. (eds), *Resource Constraints and Management Options in Mountain Watersheds of the Himalayas.* Proceedings of the PARDYP regional workshop, 8-9 December 2003. Kathmandu: ICIMOD