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Water and erosion studies in an integrated watershed management project in the Hindu Kush-Himalayas

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Abstract

In certain areas of the Hindu Kush-Himalayas, the economic and ecological situation is approaching the point of no return through gradual degradation of the mountain environment. The natural resources of these areas, in particular the water, soils, forests, pastures, and biodiversity, are under threat and, in places, are being rapidly depleted.

There is a general lack of good biophysical baseline information for the region, and little long-term monitoring has been carried out on key processes leading to degradation in the fields of soil erosion, soil fertility change, hydrometeorological issues, sedimentation, water distribution, agricultural activity, and changes in forest cover. Furthermore, the long-term impacts of new systems of participatory natural resource management on physical processes have not been studied.
The People and Resource Dynamics of Mountain Watersheds in the Hindu Kush-Himalayas project (PARDYP) provides an impetus for continuing a long-term monitoring programme that is essential for understanding the environmental dynamics and rates of change in selected watersheds of the Hindu Kush-Himalayas.

Hydrometeorological studies with a dense measurement network in five watershed across the Hindu Kush-Himalayas focus on the generation of relevant and representative information and technologies about water balance and sediment transport related to degradation on a watershed basis.

The presented paper is concerned with an introduction to the water and erosion studies of the PARDYP project, the methods and techniques applied and the philosophy of the measurement setup. It discusses the experiences of three years mainly focussing on the two watersheds in Nepal.

INTRODUCTION

The Middle Mountains of the Hindu Kush-Himalayas is the one of the most densely populated mountain area in the world and population is still growing rapidly. Daily Nepali newspapers recently reported an estimated doubling of Nepals population in 29 years (2.37% population growth) quoting United Nations Fund for Population Activities (UNFPA). With increasing population the demand for natural resources such as fodder, fuel wood, soil and water is growing rapidly. In this area water is already now a limiting factor for agricultural production during certain times of the year, fodder is becoming scarce due to degrading forests and grasslands, fertile top soil is lost to surface and gully erosion and agricultural land has expanded to marginal soils. Natural resources are being

depleted and further degradation of the natural resources become inevitable under the changing conditions in case of poor planning. The impact of these human activities does not only affect the local residents of the watersheds but also downstream areas. To what extent downstream areas are affected by the human impact on natural resources has been a long scientific debate (Ives and Messerli, 1989). The influence of deforestation in the Himalayas on the generation of the devastating floods in the lowlands of the mountain range, such as Bangladesh, has been discussed extensively (e.g. Hofer, 1998a). Hofer (1998a) questions the traditional understanding that the Himalayan farmers with their land use practices are responsible for the flooding in the lowlands of Bangladesh.

To understand the existing system an integrated approach has to be chosen for the investigation of the relevant mechanisms and the prevention of further degradation of important natural resources. The investigations however can only be done on the basis of long-term data sets, which are rarely available under present conditions. Another important factor is the scale of the focus area. Findings for the micro-level cannot automatically be extrapolated to the meso and macro levels (Bruijnzeel and Bremmer, 1989).

Feeling the need of an integrated and interdisciplinary approach to the problem with a long-term perspective the People and Resource Dynamics in Mountain Watersheds of the Hindu Kush-Himalayas Project (PARDYP) was launched in October 1996. Detailed information of the project and its objectives are provided in the following section before giving more details on the water and erosion study activities and the experience of the first three years of PARDYP.

THE PARDYP PROJECT

The People and Resource Dynamics of Mountain Watersheds in the Hindu Kush-Himalayas (PARDYP) project is a regional research for development project active in many fields of natural resource and watershed management. It succeeded two successful International Development Research Centre (IDRC) funded projects, the Mountain Resource Management and the Rehabilitation of Degraded Lands project. It combined the regional and the integrated approach from its two predecessors. In October 99 it entered into its second phase after completion of a three years Phase I.

PARDYP aims at contributing to balanced, sustainable and equitable development of mountain communities and families in the Hindu Kush-Himalayan region (ICIMOD, 1999). To reach this aim it is focusing on data exchange, generation and dissemination in major components such as the understanding of community institutions, determination of reasons for social and gender inequity, the investigation of the status and the dynamics of natural resources and the potential for improvement of the livelihood of mountain communities. The project activities range from agronomic and horticultural initiatives, socio-economic and market studies, rehabilitation of degraded lands and forestry, soil fertility studies, participatory conservation activities to water and erosion studies. All the project activities are confined to five watersheds in the Middle Mountains of the Hindu Kush-Himalayas in the countries China, India, Nepal and Pakistan (Figure 1). Selected national focal research institutions implement, manage and supervise the activities with the assistance of national and international partners and collaborators. The two main international

partners are the Institute for Resources and Environment at the University of British Columbia (UBC), Canada, and the Hydrology Group at the University of Berne (UoB), Switzerland. Overall coordination, guidance and administration are provided by the International Centre for Integrated Mountain Development (ICIMOD). Funding is received from the Swiss Agency for Development and Cooperation (SDC), IDRC and ICIMOD.

One of the major components of the project is research for development and demosntration focusing on water, erosion and related matters.

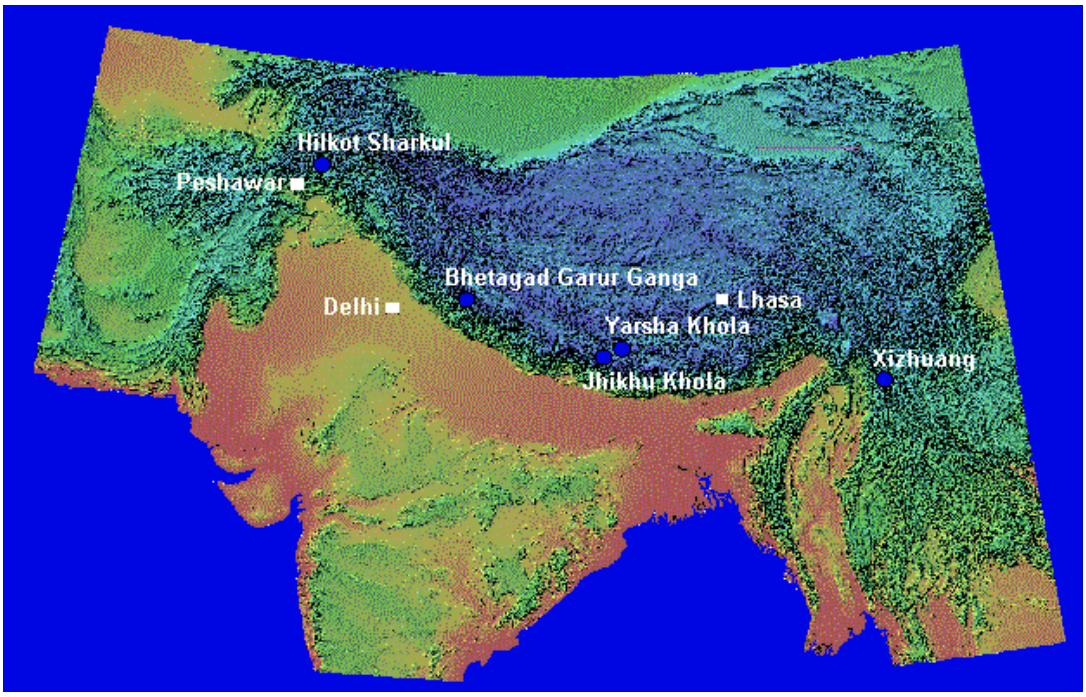

Figure 1. The five PARDYP watersheds.

WATER AND EROSION STUDIES IN PARDYP

Population pressure and climate change will affect the further development of water and erosion related issues of the Hindu Kush-Himalayan region. Presently problems in terms of water are mainly concerned with quantity. "Too much" during rainy season and "Too little" during the dry period of the year are the basic problems. With increasing population and intensifying agriculture there is no relief on the water resources in sight. In many places of the region depletion of ground water and drying up of springs is taking place. First studies in one of the Nepal watersheds have shown that mainly those communities, which live on the ridges of the watershed, are facing water problems, not only for agricultural but even for domestic purpose (Merz et al., 2000).

During monsoon however vast amounts of water are leaving the upland watersheds as surface runoff, causing erosion on the slopes, sedimentation and flood problems further

downstream. As mentioned above it has yet to be established to what extent the processes in the watersheds are affecting the downstream areas (Ives and Messerli, 1989; Bruijnzeel and Bremmer, 1989). On the farmers field rainfall events lead to fertile topsoil loss mainly during pre-monsoon season (Carver, 1997), which leads to productivity losses and water quality concerns.

The presented problems above are illustrated in Figure 2 as vicious cycle. In the context of the Himalayan Region and the discussed problem, marginal lands are those areas which are not favourable for any agricultural activity. This could be due to infertile soils, unfavourable geology or climate, and many other reasons.

To fully understand the system and the involved processes there is only little reliable data available within the region as mentioned above. However, for the assessment of possible changes and impacts long term data is required.

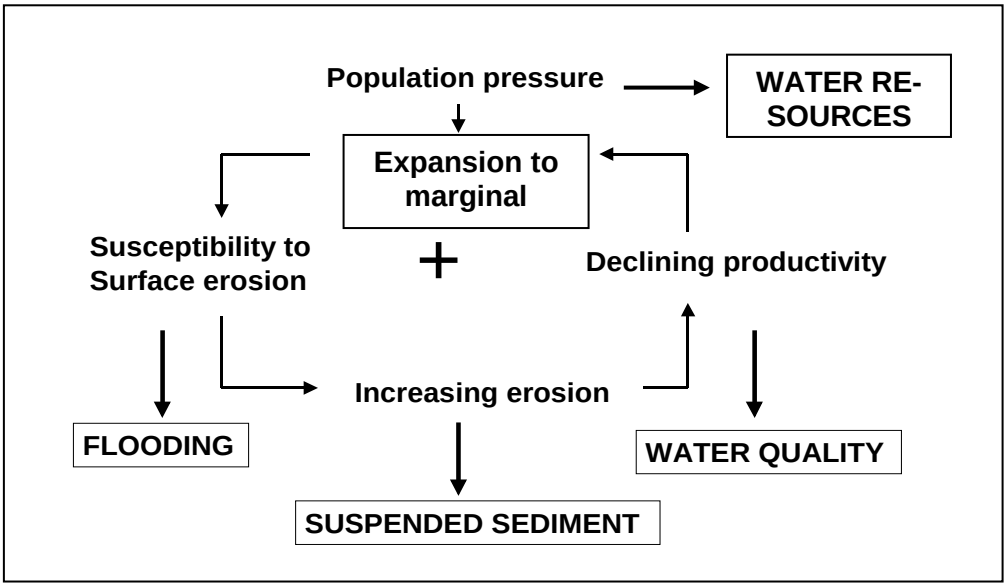

Figure 2. The influence of population pressure on water related issues.

"To generate and exchange information on water as a resource and its role in land degradation, and to identify and test options to enhance water management decisions"

This is the main specific objective of PARDYP which deals with water and erosion concerns. The water and erosion studies in PARDYP work therefore on three spatial scales (Figure 3): plot/household, watershed and regional level. The type of research questions and analyses are different depending on the scale. On a regional scale the interest may focus on flooding and its implications on human activities in lowlands or plains. The activities carried out on the watershed level would concentrate on the importance of different sub-catchments in the generation of floods or the retaining of water for sustained flow for hydropower production in small-scale hydropower schemes. On the local level the

water availability for the single farmers. might be in the center of the interest. Hofer (1998b) elaborates on this matter and gives more examples for the differences in scale depending issues.

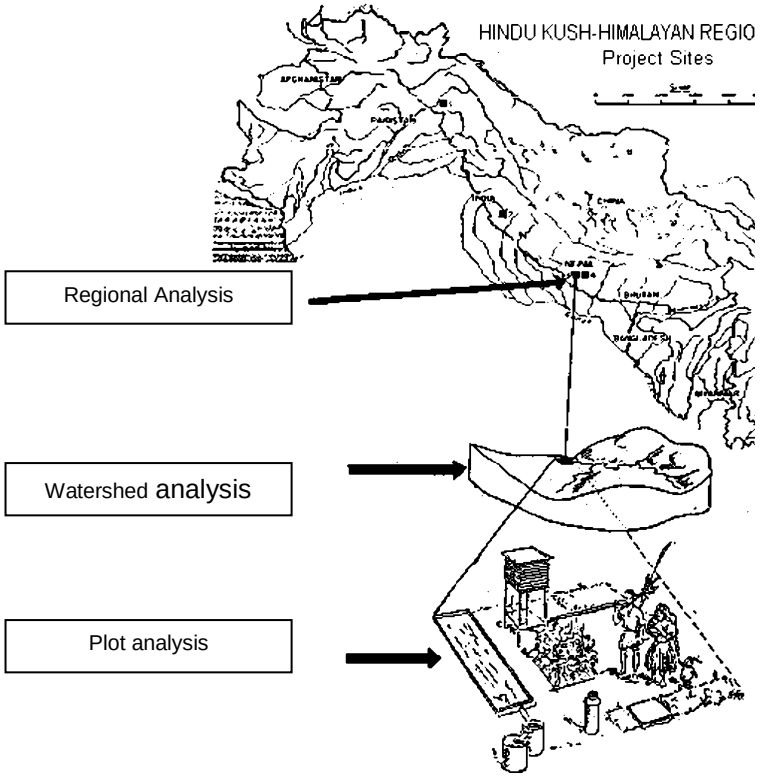

Figure 3. Spatial focus levels of the water and erosion studies in PARDYP (after Hofer, 1998b).

To meet the objective on all three spatial scales mentioned above, the activities of the PARDYP Water and Erosion Studies are based on all scales (ICIMOD, 1999). At present the major focus however is on the watershed as well as the plot level.

Data collection in five watersheds across the HKH region

Long term data collection is envisaged in a selected number of catchments within the region. The network is continuously being monitored and maintained by local staff. The staff is regularly being trained in order to obtain accurate and as much as possible comparable data. All the collected data is being thoroughly checked and stored in a database. Annually it is being published in form of a yearbook.

Data analyses in three main components

The data collected by the water and erosion measurement network will be analyzed in the three following fields:

Study of water dynamics (floods, low flows): This includes the study of rainfall distribution in time and space, high flows and their generation, low flows and their occurrence and the investigation of rainfall-runoff relationship from areas of different land use and cover. The results are of particular interest to planners and engineers involved in water related projects (irrigation, hydro power, drinking water).

Study of sediment transport and water quality : Sediment loads and their sources are of major interest for irrigation scheme and hydropower development and design. For the farmers and local users of common land resources, the loss of topsoil is of direct concern. Furthermore, sediment in drinking water supplies is also commonly high on the list of household concerns.

These studies include the calculation of sediment balances of different spatial levels and the routing of sediment from the plot level to the watershed. In a later stage possible measures against surface erosion will be tested in collaboration with farmers and proposed to the other farmers.

In addition nutrient losses in the runoff and drainage waters will be determined and compared between the different spatial levels and land use systems. Under this activity fall also water quality studies looking at the quality of drinking water in terms of chemical as well as microbiological pollution.

Study of water availability: This activity will be carried out at different spatial levels, where water availability, water losses and hence water balances will be estimated. These calculations will lead to an indication of where and when water is available, where and when water supply is critical, where water harvesting will lead to considerable benefit for the residents and farmers, and how storage can be achieved. This refers as much to drinking water supplies as to irrigation.

In addition to the topical studies mentioned above the water and erosion study team of PARDYP will conduct comparative hydrometeorological and sediment transport studies between the PARDYP watersheds and other watersheds across the region. This includes:

> the integration of the results from each watershed using GIS and other technologies in order to construct a picture of the behaviour of water and sediment in terms of time, season, land cover, and extremes;
>
> the comparison of these results and key findings between the watersheds to formulate and explain main similarities and differences across the region;
>
> the modelling of scenarios under given and changing conditions to predict changes in the flow regimes and sediment transport on a "if this, what then" basis.

Applied research and implementation

Results from the network, from plot experiments and from information from other completed or ongoing projects are being translated to implementation activities and applied research. The data of the network is for example used for the recommendation of most

suitable vegetable species under given temperature conditions. On the water front this includes activities in water harvesting from rainfall and springs in areas where water is scarce and trials with water saving techniques. Dissemination of the results as well as the data has high priority in the project.

One of the guiding principles of the project is capacity building. In the case of water and erosion studies it is the training and education of young hydrologists in the four participating countries and from outside the region. The aim is to familiarize them with new and appropriate technology in the field of water and erosion research.

PARDYP WATER AND EROSION STUDIES - THE FIRST THREE YEARS

PARDYP monitoring network and data collection

In the five PARDYP watersheds a measurement network of hydrological, meteorological stations and erosion plots was set up. A total of 93 measurement sites have been operational in March 2000, monitored by local residents who get annual training and new instructions if needed (Table 1).

Table 1. Measurement sites in the five PARDYP watersheds, March 2000.

Watershed	Hydrological stations	Meteorological stations	Erosion plots
Xi Zhuang - China	5	10	6
Bhetagad - India	6	5	4
Jhikhu Khola - Nepal	5	10	7
Yarsha Khola - Nepal	6	11	4
Hilkot - Pakistan	5	6	3

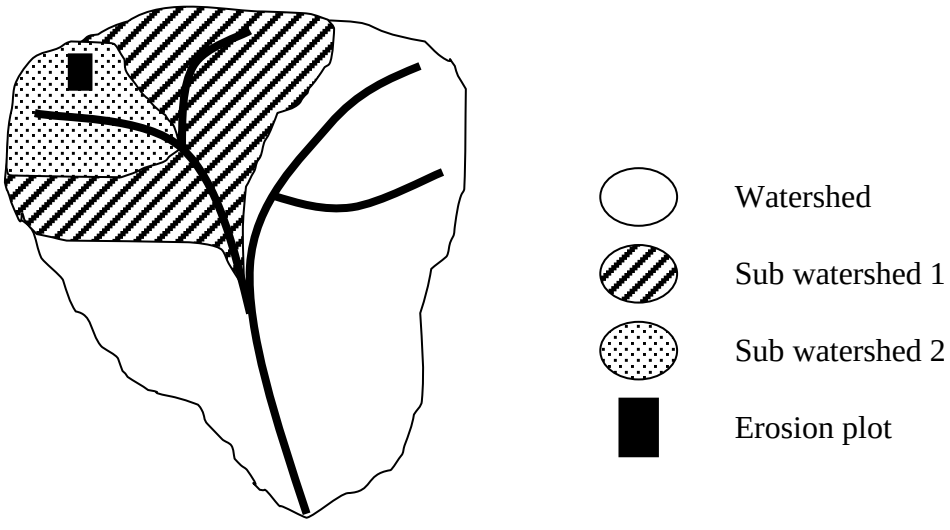

Figure 4. Nested approach in the Jhikhu Khola watershed, Nepal.

The setup of the station network in all watersheds was done after the nested approach principle. This approach allows to follow the scale dependant processes from the micro- to the meso-scale, i.e. from the plot to the watershed level. On the plot level the investigations are undertaken on erosion plots and surface flow collectors. Sub-catchments and catchments are monitored with hydrological stations equipped with different instruments. In future a extension to the regional scale in terms of a variety of analyses (regionalization) is possible. The nested approach principle is graphically presented in Figure 4.

The methods of data collection are as far as possible standardised or at least kept similar. Different manuals were prepared and distributed to the respective people in the watersheds: Discharge measurement by means of salt dilution (Merz, 1998), discharge measurement by means of current meter technique (Dongol et al., 1999) and measurement of runoff and soil loss by means of erosion plots (Nakarmi, 1999). All manuals include MS EXCEL macros for support in calculation and creation of input templates. In three of the watersheds the same equipment is used for the collection of rainfall intensity and temperature data. The monitored parameters include water level, discharge, sediment concentration, rainfall, air temperature, water quality parameters and others.

All the data is stored in a watershed database. The establishment of a regional database is envisaged in near future in order to ensure easy accessibility for all project staff to all project data. The data exchange is regulated and protected through a Code of Practice (PARDYP, 1999). From the year 2000 onwards the hydrological software HYMOS 4 is being used for data management in all five watersheds. This ensures exchangeable data sets between the different country teams and similar formats.

In Nepal a variety of surveys were undertaken during the last three years, mostly in order to obtain the necessary baseline information for further hydrological studies.

Land use was mapped with the help of aerial photographs of the scale 1:20,000. In brief, the major changes occurred in the forest cover (increase) and the rainfed agricultural areas (decrease) in the last 15 years in the case of the Yarsha Khola. In the Jhikhu Khola forest cover and rainfed agricultural area have increased, shrub and grass land has decreased between 1972 and 1990. Shrestha (1996) and Shrestha (2000) discuss the results in detail.

In both watersheds of Nepal geological baseline maps give information on the geological underground of the watersheds (Nakarmi, 2000). In the case of the Jhikhu Khola a geomorphical map exists and soil information is available for parts of the watershed.

During December 1998 and September 1999 a Water Need and Supply Survey was done in the Yarsha Khola, in the Jhikhu Khola respectively, in order to give indication on water surplus and water demand areas. The results of the surveys are presented in Merz et al. (2000) and Merz and Nakarmi (in prep). For the allocation of water resources a detailed spring survey was done in the Jhikhu Khola. A total of 319 springs were mapped and basic physical parameters measured. Selected springs are now monitored for quality issues (see below Water Chemistry).

Data analyses

The first three years were mainly taken up by the setup of the measurement network. Most of the data has therefore not been analyzed yet. However, as it was early realized that the aim of the project was not only data collection but also data analysis the project staff involved in water and erosion studies were trained in hydrological data analysis. A training workshop was held in Kathmandu with the main topics “basic analysis”, “low flow”, “water availability”, “high flow” and “sediment analysis tools”. For the occasion of the training a manual on water and erosion analysis methods was produced, which could also be valuable to other watershed management projects (Merz and Weingartner (eds.) (in prep).

Phase 2 of the project will now mainly emphasize on the data analyses next to the routine data collection.

Data application in the Nepal watersheds

To date the practical applications of the collected data as well as of the research findings are:

Education: Watershed management and Natural resources management is part of the curriculum for obtaining the School Leaving Certificate in Nepal. The data obtained by the project has been used by local high schools for the respective courses. Yearbooks were distributed to the different schools in the watershed. At University level PARDYP staff are involved in the preparation of lectures in courses of the Department of Biological and Environmental Science, Kathmandu University. Several regional and international students have used and are using the data of the project watersheds for their BSc, MSc and PhD theses.

Agriculture: In the Jhikhu Khola watershed the meteorological data is used by a local NGO for the recommendation of suitable vegetable crops for given conditions. Alternative water application methods are studied in integrated manner with agricultural entomologists and agronomists. A study on the irrigation efficiency is being conducted in collaboration with the Institute of Engineering, Tribhuvan University.

Water harvesting: The PARDYP project has a strong interest in improving the efficiency of water use. This starts with the retention of rainfall and storm water. In the Jhikhu Khola watershed a trial site for the retention of storm water was constructed in collaboration with a Chinese expert (Nakarmi and Neupane, 1999). The knowledge of rainfall patterns and runoff coefficients helped in the design of the system. Another system of the same type was constructed in the Yarsha Khola watershed.

A trial on alternative irrigation methods was conducted with the water from the constructed underground tank. Bucket and sprinkler irrigation were under investigation.

It was decided that in mid 2000 trials on rainwater harvesting would be initiated with the help of the jar technique as implemented by the Finnida supported Rural Water Supply and Sanitation Support Programme in Nepal. This water will mainly be used for drinking and domestic purposes.

Water chemistry: PARDYP Nepal is undertaking a water quality assessment study in collaboration with the Department of Environmental and Biological Sciences of the Kathmandu University. This study, funded by the Australian Agency for International Development (AusAid), aims at

assessing the present water quality of the Jhikhu Khola and its tributaries;
examining the water quality of the public water supply;
raising public awareness of water quality issues;
recommending simple water quality assessment methods and treatment technologies.

CONCLUSION

One of the major achievements of the project up to date is the comparable data sets for four watersheds in five countries. Three years of data in hydrological terms however is no data. Further monitoring is therefore essential. After Phase 2 of the PARDYP project a time series of 4 to 6 years will be available. A number of analyses with hopefully promising and relevant results will then be possible.

In near future there will be more emphasis given on the application of the collected data. A study on hydrological models for the purpose of design has been initiated in order to give recommendations to consulting and government agencies for the Middle Mountains region. A study on the survival and effectiveness of different premonsoon cover crops has been designed and will be implemented during the next dry season. This is done on the basis of monitoring results up to date. Major focus will still be on the capacity building of young and enthusiastic scientists who will be future employees of government agencies and NGOs.

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References

Bruijnzeel, L.A.; Bremmer, C.N. (1989), "Higland-lowland interactions in the Ganges Brahmaputra River basin: A review of published literature", ICIMOD Occasional Paper No. 11, Kathmandu.

Carver, M. (1997), "Diagnosis of Headwater Sediment Dynamics in Nepal's Middle Mountains: Implications for Land Management", Unpublished PhD Thesis at University of British Columbia, Vancouver.

Dongol, B.S.; Dhakal, M.P.; Merz, J. (1998), "Discharge measurement by means of current meter technique", Internal Working Paper. PARDYP, Kathmandu.

Hofer, T. (1998a) "Floods in Bangladesh – A Highland-Lowland Interaction?", Geographica Bernensia G48, Bern.

Hofer, T. (1998b), "Hydrometeorological Measurements and Analysis in Interdisciplinary Watershed Projects". Discussion Paper No. MNR 98/3. International Centre for Integrated Mountain Development, Kathmandu.

ICIMOD (1999), "PARDYP – The Project Document", International Centre for Integrated Mountain Development, Kathmandu.

Ives, J.D.; Messerli, B. (1989), "The Himalayan Dilemma. Reconciling development and conservation", Routledge, London.

Merz, J. (1998), "Discharge measurement by means of salt dilution", Internal. Working Paper, PARDYP, Kathmandu.

Merz, J.; Shrestha, B.; Dongol, B.S.; Dhakal, M.P.; Weingartner, R. (2000), "An Assessment of the water need and supply situation in a rural watershed of the Middle Mountains in Nepal", In "PARDYP – research for Development in the HKH – The First Three Years (1996 to 1999)", ICIMOD, Kathmandu.

Merz, J.; Nakarmi, G. (submitted), "Water availability in rural watersheds of the Middle Mountains in Nepal", Submitted to the International Symposia on the Himalayan Environments to be held in Kathamndu, November 2000.

Merz J.; Weingartner, R. (eds.) (in prep.), "Water and Erosion Analysis Manual. Manual" Manual for PARDYP, Kathmandu.

Nakarmi, G. (1999), "Measurement of runoff and soil loss by means of erosion plots", Internal Working Paper. PARDYP, Kathmandu.

Nakarmi, G.; Neupane, P. (1999), "Construction of a Water Harvesting Tank – Experience from Kubinde in the Jhikhu Khola Watershed, Nepal", In "PARDYP – research for Development in the HKH – The First Three Years (1996 to 1999)", ICIMOD, Kathmandu.

Nakarmi, G. (2000), "Geological mapping and its importance for construction material, water chemistry and terrain stability in the Jhikhu Khola and Yarsha Khola Watersheds of Nepal", In "PARDYP – research for Development in the HKH – The First Three Years (1996 to 1999)", ICIMOD, Kathmandu.

PARDYP (1999), "Code of Practice for Data Exchange", Internal Working Paper PARDYP, Kathmandu.

Shrestha, B. and Brown, S. (1995), "Land Use Dynamics and Intensification. In Schreier, H. et al. (eds), "Challenge in Mountain Resources Management in Nepal – Processes, Trends, and Dynamics in Middle Mountain Watersheds. Proceedings, Jhikhu Khola, ICIMOD/IDRC, Kathmandu.

Shrestha, B. 2000: Population Dynamics and Land Use in the Yarsha Khola Watershed", In "PARDYP – research for Development in the HKH – The First Three Years (1996 to 1999)", ICIMOD, Kathmandu.