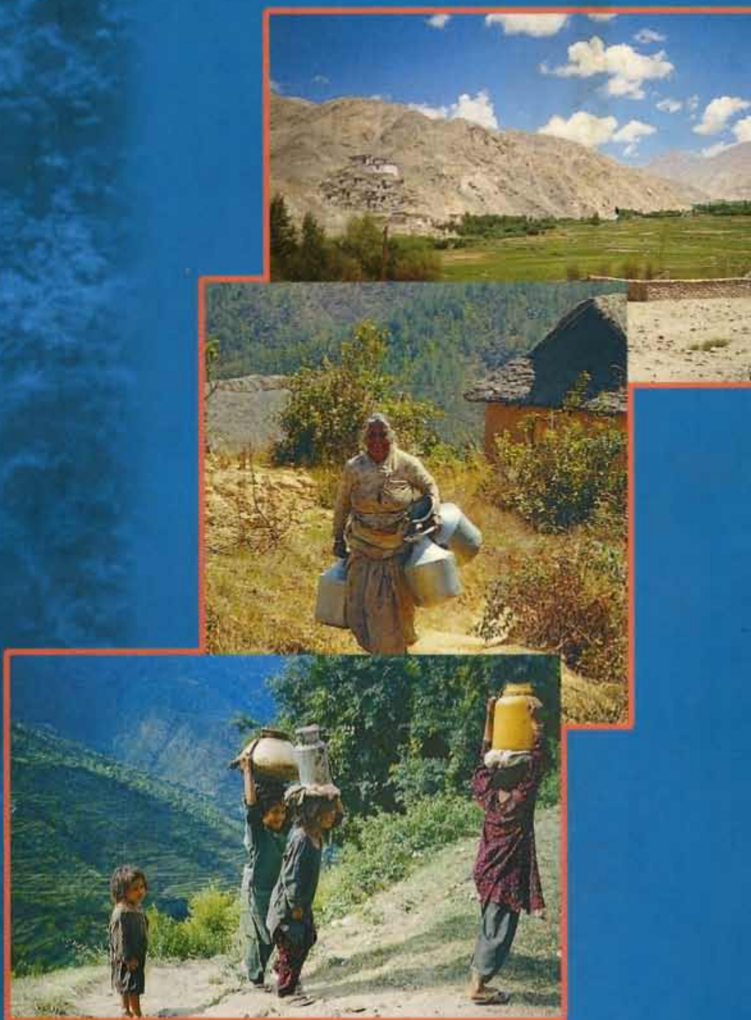
Waters of Life

Perspectives of Water Harvesting in the HKH



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ICIMOD

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Perspectives of Water Harvesting in the Hindu Kush-Himalayas

Proceedings of the Regional Workshop on Local Water Harvesting for Mountain Housesholds in the Hindu Kush-Himalayas
Kathmandu, March 14-16, 1999

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International Centre for Integrated Mountain Development
Kathmandu, Nepal
2000

Credit: All plates by Suresh Raj Chalise

Cover:

Background	Waterfall close to Khasa near Nepal-China (Tibet) border
Top Right	Water brings life to the cold desert, Ladakh, India
Centre	An old lady walking up hill to fetch water, Bajrapare village, Kabhrepalanchok, Nepal
Bottom right	Little girls with a big burden: children fetching daily water supplies, Tehri Garhwal, India.
Back page	Rara Lake, 3,000 masl

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

ISBN 92 9115 104 1
Vol. I 92 9115 118 1

Editorial Team: Greta Mary Rana (Senior Editor)
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Typesetting at
ICIMOD Publications' Unit

Foreword

Water is fundamental to the material basis of both life and livelihoods in rural Asia. Water serves a variety of purposes: it is used not only for irrigating the main field crops, but also for domestic needs such as drinking, washing, and bathing and for home gardens, livestock, trees, and other permanent vegetation. Other productive uses include aquaculture, transportation, and small rural enterprises such as brick making. The environmental benefits of water resources include direct uses such as the harvesting of aquatic plants and animals and the immeasurable benefits of biodiversity and maintaining natural ecosystems. Many of the traditional water-harvesting systems have fallen into disuse or have been forgotten, replaced by 'modern' structures and systems that have failed to meet the expectations and demands of growing populations. Water scarcity affects the rural household, economy, and environment in multifarious ways, resulting in hardships such as the necessity of carrying heavy pots of water several kilometres every day to meet household needs; the destitution of farmers and their families who lose their lands, or of the landless who lose their jobs because of lack of water for irrigation; the loss of wetlands and estuaries because of water depletion upstream; and increasing health problems caused by water-borne diseases and pollution. Inequitable access and a distribution system skewed in favour of the urban, rich and powerful further compound the problem of absolute scarcity, especially for the poor and the disadvantaged.

Concomitantly with growing scarcity, competition over water among various uses and users is intensifying, both within and between sectors. Demands for water supplies for agriculture, households, and industry have escalated dramatically in recent decades. Increasingly, wetlands, rivers, and estuaries that support wildlife and vegetation are being threatened by water transfer and shortage. While water for irrigation remains critical for food production and rural incomes, farmers must compete for the resource among themselves and with rapidly growing industrial, domestic, and urban demands for water. In the competition for water, industrial and urban needs typically receive priority over agriculture and irrigation, which in turn are favoured over domestic uses (generally considered the domain of women) or ecosystem needs. 'Environment versus development' dilemmas over water have led to conflicts and struggles related to large dams, industrial pollution, chemical runoff from agriculture, and aquaculture, among other issues. Often, as water resources have fallen under centralized and state control through bureaucracies, policies, and legal instruments, communities have had to struggle to maintain their rights, customary local practices, and livelihoods. With towns and industries making more and more claims on the water currently used in rural areas, the rural poor and marginalised groups have little means to defend their rights to water and are unlikely to even gain a seat at the table in discussions about the best way to manage diminishing water resources.

Simultaneously, a better understanding by the public and policy-makers of resource limits and the urgency of taking effective action to meet the challenge is needed. In the face of increasing water scarcity and competitive demands on water, water security will be increasingly linked to poverty eradication, governance, and conflict resolution. In the meantime, rapidly evolving water markets are establishing their own means of rationing water in many parts of Asia. Water is increasingly being treated as a commodity to facilitate mobility between competing demands and purchasing capacities; in short, going to those who have the ability and willingness to pay. But treating water as a commodity may only further marginalise the weaker sections of society who have minimal purchasing capacity and are unable to defend their prior use of water. Water is imbued with deep cultural significance all over the world, especially in rural Asia. Conflicts over water evoke meanings and images that go beyond the physical attributes of water. After all, denial of access to water is ultimately denial of life itself.

ICIMOD must be commended for bringing out these two volumes on the significance and the diversity of water-harvesting technologies and institutions governing them. Apart from the publication of these volumes, ICIMOD has been instrumental in bringing people and institutions from different countries together to share their experiences of the dynamics of policies and practices revolving around water-harvesting structures and the local economy. In pursuing this interest on a vital resource for livelihoods in the Hindu Kush mountains, we hope that the further research and programme activities of ICIMOD will seek to enhance and sustain the role and voice of local communities in governing these community assets and also continue to identify policies, practices, movements, and institutional capacities that increase disadvantaged people's access and control over water resources.

Ujjwal Pradhan
New Delhi

March 2000

Preface

A commonly held notion about mountain areas is that these are all plentifully endowed with water, and mountain communities should not be facing too much difficulty in accessing needed water supplies. These two volumes, discussing efforts by local communities to harness water resources for drinking and agriculture, show clearly that plentiful endowment does not necessarily mean it is readily available. Water for the settlements and fields of mountain households had become increasingly scarce. Tapping more distant sources has many technical, environmental, and socio-institutional implications as the discussions in these two volumes indicate.

ICIMOD's main objective in bringing out these two volumes is first to close some of the continuing knowledge gaps about the use of resources by mountain communities. It is hoped that by a better understanding of prevailing practices it will contribute towards the development of sustainable systems in the future. Another important reason is that this is also the year of the World Water Vision and it would be a gross oversight if mountain communities did not have a place in this vision. We hope this small contribution will help in this direction.

ICIMOD is very grateful to the Ford Foundation for supporting the water harvesting programme of the Centre which has made this review work possible. The contributions of all the national and local organizations, including the authors of the various papers and case studies, are also highly appreciated. Dr. M. Banskota, Deputy Director General and Professor S.R. Chalise, Water Resources' Specialist, planned the outline and contents of these documents and ensured that all critical issues were covered. Obviously much more can be said about important topics like water and mountain communities. This is only a small step forward towards improving our understanding about water harvesting at community level in the Hindu Kush-Himalayas. ICIMOD is looking forward to taking the next steps that should include, in particular, capacity building in local planning and management of water-harvesting systems.

Abstract

The Hindu Kush-Himalayas (HKH) are the largest storehouse of fresh water in the lower latitudes and as such are important water towers for nearly 500 million people. They are the source of major river systems: the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, and the Mekong. Also called the 'Third Pole' they contain the largest mass of ice and snow outside the earth's polar regions. Located at the highest elevations on earth, with the permanent snowline at about 5,000 m, the mountain peaks of the HKH extend close to 9,000 m. These peaks contain many glaciers, including some of the longest outside the polar regions. Availability of water at such great heights has also made human life possible at higher elevations than elsewhere, with human settlements beyond even 4,000 m and temporary and seasonal settlements with unique cultures and traditions even close to 6,000 m. The extreme variability of climate and precipitation patterns, as well as extremely inadequate knowledge on the hydrology of the HKH rivers and streams and the complex interrelationships between ecology and hydrology in the region impose serious scientific and technical limitations on the development of HKH waters. This two-volume document discusses the methods of harvesting water throughout the HKH mountains amongst a wide variety of human groups, focussing on the efforts being made by local communities for harvesting water. Many of the older systems are breaking down while newer ones supported by government and development organizations are limited. A concerted effort is needed to improve existing systems through community participation while at the same time expandings new systems.

Contents

Acronyms

ADB/N	:	Asian Development Bank, Nepal
ARWSP	:	Accelerated Rural Water Supply Programme
AZRI	:	Arid Zone Research Institute
BOARD	:	Rural Water Supply and Sanitation Fund Development Board
BWMP	:	Bagmati Watershed Management Project
CAPART	:	Council for Advancement of People's Action and Rural Technology
CBO	:	Community Based Organization
CDO	:	Chief District Officer
CGI	:	Corrugated Galvanized Iron
CIDA	:	Canadian International Development Agency
CSWCRTI	:	Central Soil and Water Conservation Research and Training Institute
DDC	:	District Development Committee
DSCWM	:	Department of Soil Conservation and Watershed Management
DWRC	:	District Water Resources Committee
DWSCC	:	District Water Supply Coordination Committee
DWSS	:	Department of Water Supply and Sanitation
FINNIDA	:	Finnish International Development Agency
FMIS	:	Farmer Managed Irrigation System
FRIEND	:	Flow Regimes from International Experimental and Network Data
FYP	:	Five Year Plan
GIS	:	Geographic Information Systems
GLOF	:	Glacial Lake Outburst Flood
HDPE	:	High density polyethene
HH	:	Household
HKH	:	Hindu Kush-Himalayas
HKH-FRIEND	:	Hindu Kush-Himalayan Flow Regimes from International Experimental and Network Data
HMG/N	:	His Majesty's Government of Nepal
HYV	:	High Yielding Variety
ICARDA	:	International Centre for Agricultural Research in Dry Areas
ICIMOD	:	International Centre for Integrated Mountain Development
IDE	:	International Development Enterprise
IHP	:	International Hydrological Programme
IIDS	:	Institute for Integrated Development Studies
ILO	:	International Labour Organization
INGO	:	International Non-Governmental Organization
INSAN	:	Institute for Sustainable Agriculture
IP	:	Irrigation Policy
IPCC	:	Intergovernmental Panel on Climate Change

LWHS	:	Local Water Harvesting Systems
MLD	:	Ministry of Local Development
MOWR/DOI	:	Ministry of Water Resources/Department of Irrigation
NGO	:	Non-Governmental Organization
NWFP	:	North West Frontier Province
NWSC	:	Nepal Water Supply and Sanitation Corporation
O and M	:	Operation and Maintenance
PARK	:	Pakistan Agricultural Research Council
PCRWR	:	Pakistan Council of Research in Water Resources
PIM	:	Participatory Irrigation Management
R and D	:	Research and Development
REFRESHA	:	Regional Flow Regime Estimation for Small Hydropower Agreement
RWHU	:	Rainwater Harvesting and Utilisation
RWSSP/F	:	Rural Water Supply and Sanitation Project/FINNIDA,
SAARC	:	South Asian Association for Regional Cooperation
SAPPROS	:	Support Activities for the Poor Producers of Nepal
SAPROS	:	An NGO based in Kathmandu
SWC	:	Social Welfare Council
UDLE	:	Urban Development through Local Efforts
UG	:	User Groups
UNESCO	:	United Nations Educational Scientific and Cultural Organization
VDC	:	Village Development Committee
WARM	:	Water Resources' Management
WECS	:	Water and Energy Commission Secretariat
WHS	:	Water-harvesting Systems
WMO	:	World Meteorology Organization
WUA	:	Water Users' Association
WUC	:	Water Users' Committee

Chapter 1
Introduction

Background

All of the world's major rivers have their headwaters in the mountains. Over half of humanity relies on the fresh water accumulating in the mountains for drinking, domestic use, irrigation, hydropower, industry, and transportation. Mountain areas constitute a relatively small proportion of river basins, yet they provide the greater part of the river flows downstream. These 'water towers' are crucial to the welfare of humankind. As demand increases, the potential for conflict over the use of mountain waters grows. Careful management of mountain water resources must therefore become a global priority in a world moving towards a water crisis in the next century.

The Hindu Kush-Himalayas (HKH) are the largest storehouse of fresh water in the lower latitudes and as such are important water towers for nearly 500 million people. They are the source of major river systems: the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, and the Mekong. These mountains are also called the 'Third Pole' as they contain the largest mass of ice and snow outside the earth's polar regions. Located at the highest elevations on earth, with the permanent snowline at about 5,000 m, the mountain peaks of the HKH extend close to 9,000 m. These peaks contain many glaciers, including some of the longest outside the polar regions. Availability of water at such great heights has also made human life possible at higher elevations than elsewhere, with human settlements beyond even 4,000 m and temporary and seasonal settlements with unique cultures and traditions even close to 6,000 m.

The extreme variability of climate and precipitation patterns, as well as extremely inadequate knowledge on the hydrology of the HKH rivers and streams and the complex interrelationships between ecology and hydrology in the region impose serious scientific and technical limitations on the development of HKH waters. In general, hydrological data are restricted and not available freely for research in the HKH. Even spatial data and maps are not easily available. Such limitations make it difficult to improve the knowledge base that is essential for dealing with existing uncertainties associated with variability in climates and precipitation. In addition, unknown factors concerning the impacts of global warming and climate change complicate the problem.

Water, as one of the region's most important natural resources and one that is critical for the survival of mountain people, cannot and must not be ignored. At this point, it has been so widely politicised that it has become an emotional issue. Persuading the HKH countries to look at water issues objectively and dispassionately has been a difficult task. Unfortunately, the mistrust and conflicts that exist in the region concerning transboundary river waters have accumulated over the last 50 years and are difficult to dispel, particularly because facts and figures are either not available or non-existent. The issue is complicated since, in many cases, the headwaters of major rivers lie in disputed territories. These factors do not encourage a comprehensive approach to data collection, research, and planning for the overall development of water in the region.

In line with this context, the programme of the International Centre for Integrated Mountain Development (ICIMOD) on water during its first ten years was confined to publication of technical reviews on issues concerning the hydrological aspects of regional waters and organizing meetings to initiate regional dialogue in order to establish a regional research network on hydrology. ICIMOD took particular care not to undertake an independent programme on water at the regional level, and most activities were undertaken in collaboration with national institutions and other agencies. Many activities took place within the framework of the International Hydrological Programme (IHP) of the United Nations Educational Scientific and Cultural Organization (UNESCO) and the Operational Hydrological Programme (OHP) of the World Meteorology Organization (WMO).

A major achievement was the successful launching of the Hindu Kush-Himalayan Flow Regimes from International Experimental and Network Data (HKH-FRIEND) project in close collaboration with the International Hydrological Programme (IHP) of UNESCO. This project has already been endorsed by six of the eight HKH countries (with the exception of India and Bhutan). ICIMOD's past work on hydrology and climate have gained credence at regional and international levels. Its interaction, linkages, and collaboration with relevant national and regional institutions, professional societies, international agencies and programmes, and universities and institutions in developed countries concerned with hydrology, water resources, and climate have grown considerably. Key activities, including an International Conference on Ecohydrology in 1996, were undertaken. Another outcome is the new project, Regional Flow Regime Estimation for Small Hydropower Agreement (REFRESHA), which is being implemented jointly with the Institute of Hydrology of the United Kingdom (UK).

ROLE OF COMMUNITY INSTITUTIONS

Mountain communities have developed diverse strategies for the management of water. Strategies have varied in accordance with local climates, bio-geophysical conditions, available technical know-how, and particular needs for water, whether for household consumption, irrigation, or other uses. These indigenous systems of water management vary widely from the mainly arid west to the largely wet eastern parts of the HKH. Strong community participation and management of such systems are important common features throughout an otherwise highly heterogeneous area. Local ingenuity and skills have been applied over the ages to store and use water to meet year-round needs and to develop agricultural systems.

A 'Regional Consultative Meeting on Water Harvesting for Mountain Households in the HKH' was organized by ICIMOD from 9-14 April, 1997, in Chengdu, Sichuan (China), in collaboration with the Institute of Mountain Hazards and Environment. The meeting emphasised that, as water is a scarce commodity for the nearly 140 million people in the HKH region, improved water-harvesting practices are critical for ensuring the availability of drinking water for mountain households, production of food grains, providing sufficient biomass, and for improved living conditions. Efficient water use and harvesting methods also improve the condition of other natural resources, thereby improving the reliability of water supply systems. People's active participation in all aspects of water use, harvesting, and management has contributed to the equity and sustainability of local systems.

In view of the need for rapid and substantial improvements in the management of local water resources in mountain watersheds, the Regional Meeting called on ICIMOD and other collaborating partners to undertake a variety of activities. It also identified the need for research and dissemination of information in a number of areas: people's institutions related to water harvesting and their planning, implementation, maintenance, sharing, raising resources, resolving conflicts, and women's role in water harvesting. Inventories of water harvesting technologies and assessment of costs, benefits, and potentials for replication are needed. It was also recommended that databases should be developed on different aspects of hydrology, meteorology, geomorphology, geology, and biology. The environmental impacts of different water-harvesting systems were also recommended for study.

The roles of different organizations in local-level water harvesting and their capabilities in terms of meeting new challenges require investigation. In this respect examination of a decentralized policy on water harvesting was also recommended. Training at both technical and farmer levels to include exchange visits and study tours to share information about different aspects of water harvesting and improve awareness about sustainable water harvesting systems was to be organized.

The meeting discussed critical issues of governance, institutional mechanisms, equity, and micro-level responses to macro-problems. Emphasis was placed on integrating new approaches and priorities with traditional knowledge to meet local needs and build capacities/capabilities at all levels. In this context, ICIMOD's role as a facilitator in bringing together different countries, different professionals, and different policy-makers was accentuated as a way of promoting linkages.

Following the 1997 Chengdu Meeting, a regional project on Sustainable Water Harvesting Technologies and Management Systems was launched by ICIMOD with support from the Ford Foundation. The main focus of this project is on assessing and improving ways of meeting the needs for water for the households of marginalised mountain farmers, including those living in the cold arid and rainshadow areas of the HKH. In order to take stock of the existing situation vis a vis water harvesting, five policy reviews and six case studies (including three case studies from the cold arid and rainshadow areas) were undertaken in collaboration with national institutions in five HKH countries. These studies were presented at the Regional Workshop in March 1999.

The Workshop

The Regional Workshop on 'Sustainable Water Harvesting and Management in the Hindu Kush-Himalayas' was organized to discuss the findings of the six case studies carried out in the rainshadow areas and mid-hills of India, Nepal, and Pakistan and five country reviews on policies/ programmes and institutions in Bhutan, China, India, Nepal, and Pakistan. It was held at ICIMOD headquarters from March 14-16, 1999. All the papers discussed in this meeting have been presented in Volume 2 of this document.

The main objective of this workshop was to identify ways to improve and sustain local water-harvesting systems in selected mountain areas of the Hindu Kush-Himalayan region. More specifically this workshop was held to:

- develop a better understanding of the technical, organizational,and managerial aspects of Local Water Harvesting Systems (LWHS) in micro-watersheds of selected mountain areas;
- evaluate the extent to which local water-harvesting systems have an impact on and are influenced by gender and environmental considerations;
- assess the prevailing policies for water and other related areas in terms of their impact on water harvesting and management practices and identify where changes are needed to improve and sustain LWHS; and
- collect information on future directions for water-harvesting practices, policies, and management systems.

SUSTAINABLE WATER HARVESTING AND MANAGEMENT AND ICIMOD

Dr. Mahesh Banskota, Deputy Director General of ICIMOD, in his welcoming remarks to the workshop, highlighted ICIMOD's activities in water resource development in the HKH Region.

'Sustainable Water Harvesting and Management in the Hindu Kush-Himalayan Region is clearly a subject of great importance to the people in the Region because of the daily struggle of mountain communities, particularly mountain women, to collect sufficient water. Although mountain areas have been referred to as water towers, it is indeed ironical to find that most mountain communities face enormous difficulties in getting sufficient water. It is therefore not surprising to find that relatively simple but durable systems that were used to tap multiple sources of water have worked reasonably well for a fairly long period of time. Yet, more recently, on account of different factors, these systems are simply unable to cope with the demands and are slowly falling apart, some due to sheer negligence, others due to conflicts, and still others because there is no more water in the system'.

'Each period has its dominant development clichés. Today they are liberalisation and privatisation. As the after effects are seen in terms of rising unemployment, some toning down of these clichés is already evident. It was the need for rapid development several decades ago that provided the rationale for rapid expansion in the state machinery, and yet it is these very same development needs that are today calling for retrenchment of the state to make more room for other stakeholders. Better governance and civil society are the latest buzz words. This debate has also coloured mountain waters to some extent'.

'Water harvesting, water management, water resource development, and, the most recent, sustainable water resource management are among the most commonly used terms in recent discussions. The prevailing water-harvesting systems have been described as either community-/farmer-based or government-managed. The characteristics of the former are a high degree of labour intensity, based on local resources and indigenous know-how, and they are easy to maintain even when there are frequent breakdowns. The highlights of the latter are extremely capital intensive, engineering dominated, and mostly based on non-local inputs. If the former is seen as having deep roots in the community with strong local commitment and ownership, the latter has been described as contract work in which the contractor or the builder 'comes, builds, and goes'. The builder is not to be seen after the project is 'handed over'. Why has such a dichotomy continued to persist? The local systems are badly in need of a shot in the arm to prevent them from further languishing, while most government-operated systems are too costly and separated from the very people they are meant to help?'

'If farmer-based systems have such strong roots in the community, why are the communities allowing these critical lifelines to fall apart? In other systems, there is certainly an advantage of better materials and, to some extent, even better technology, and the question is why this cannot find a better base within the community instead of being only externally driven? Surely there must be a better way to integrate the best of both these systems so that mountain women can have drinking water closer to their homes and mountain farmers can improve food security through assured access to irrigation water?'

'Although the water resources' programme at ICIMOD is quite recent, its key role in mountain development has always been recognised. The main question was to identify the most appropriate area for the centre to work in a meaningful manner. There were many aspects of the subject in which the Centre did not see a role for itself. Areas have now been narrowed down, and these have been identified in the Second Regional Collaborative programme of ICIMOD, covering the period from 1999 to 2002. The areas are local water-harvesting systems, a database on water resources, and mitigation and management of water-related hazards. The future research and training activities of the Centre will focus on these areas'.

'The Centre started the water programme with a small amount of seed money, and this has been successful in attracting additional resources from Ford Foundation to undertake activities such as those being reviewed at this meeting. Support has also been received from the Government of Japan, UNESCO/IHP, and a number of other organizations for work on the database, training, and hazard mitigation in the context of water resources. ICIMOD is also very pleased to announce that the Ford Foundation is considering providing support for the next three years to develop some of the ongoing research work in this subject. ICIMOD appreciated the strong and continuing support of the Ford Foundation for not only this programme but also for a number of other areas in natural resource management'.

WATER HARVESTING IN THE MOUNTAINS: PRIORITY AREAS AND ISSUES FOR ACTION

Dr. Ujjwal Pradhan from the Ford Foundation pointed out that in the past not enough attention had been paid to the problems of water for mountain communities in rainshadow areas. He stressed the need for research on small structures. He suggested that non-government organizations, governments, and communities should work together to supplement each other's efforts. He also emphasised the need to pay attention to promotion of local governance and local control for multiple uses of water. He stressed that policies, institutions, and power relationships at various levels that have a bearing on local water harvesting need greater attention.

It was necessary to de-mystify water-harvesting policies. It was also important to know how the policies impact households and communities and what kind of policies were needed. Policies change with time, and they will be forever evolving.

Similarly, it was important to know what kind of institutions were needed to respond effectively to the needs of mountain people at the household and community levels. It was important to incorporate local and customary laws in formulating policies for sharing local waters. Another important issue was that of integration, particularly by taking note of power relationships at various levels. Bridging the gap between the interests of the state and those of a particular locality regarding the use and management of water resources was a major challenge both for policy-makers as well as for efficient implementation.

While looking for best practices in water-harvesting systems, it was just as important to look for failures. Assessment of both successes and failures was necessary if water management was to move in a sustainable direction in future.

A number of papers attempted to provide a regional perspective on different aspects of water harvesting. The book is divided into two volumes. Volume One contains the background information and a general overview of issues: water, water harvesting and practices, policies, and social dimensions of water harvesting. It also contains an annex table on hydropower potential (p27) and on the workshop (Annexes 1 and 2). Volume One also contains an annotated bibliography on water harvesting. This bibliography provides useful information for general readers as well as researchers interested in various aspects of local water harvesting in the Hindu Kush-Himalayan countries.

The policy reviews and case studies undertaken in five countries of the HKH can be found in Volume Two. The papers included in this volume are edited versions of individual papers dealing with national policies on water and water harvesting in the mountainous regions of these countries and were prepared by authors from these countries. Volume Two also contains six case studies on local water-harvesting technology and management. These case studies were carried out in two diverse climatic and water regimes of the HKH. Three are on the populous middle mountain regions of the HKH; viz., Tehri Garhwal (India), Kabhrepalanchok (Nepal), and Mansehra, NWFP (Pakistan), and the other three case studies are on the cold arid and rain-shadow areas of Ladakh (India), Mustang (Nepal), and Balochistan (Pakistan).

POLICY REVIEWS

Water harvesting and conservation have to go together. Water harvesting and protection of water bodies should be important components of national water policies. National water policies, along with specific and deliberate water policies for specific areas of hardship caused by water shortage, should be evolved through national-level dialogues and debates among NGOs, local level communities, national experts, and stakeholders. The following section highlights water-harvesting policies in the HKH countries.

In **Bhutan**, there is no specific policy for water harvesting at present. However, there are guidelines for water harvesting for irrigation and drinking water. Regarding irrigation development, the Land Act stipulates that, while harvesting water for irrigation, it should not cause damage to others' land, house, or plantation. Use of water jointly harvested should be shared among the beneficiaries of the system either through mutual understanding or through existing practice. There was no formal policy to guide the development of the drinking water policy. However, the rural water supply and sanitation unit of the Health Division formulated several guidelines to facilitate their activities. The overall goal of this programme was to improve public health by reducing the incidence of water borne and filth borne disease through provision of safe drinking water and adequate sanitation facilities (Volume 2, Chapter 1).

Mountain regions in **China** account for 70 per cent of its territory. Water scarcity is prominent in these areas. Water scarcity coincides with a high incidence of poverty. The

Chinese Government places importance on and has introduced many relevant policies for water harvesting (Volume 2, Chapter 2).

Water harvesting in mountain areas has received high priority. Investments have been made in water-harvesting projects. The national policy of China addresses the problem of poverty through water harvesting and seeks to ensure water supplies for domestic use as well as for agricultural purposes. In 1984, a specific policy on poverty alleviation was introduced and water harvesting is an important component of it.

In **India**, the National Water Policy (1987) is considered to be a landmark in development of the water sector. It was the first time a policy for planning, developing, and conserving scarce water resources in an integrated manner and on an environmentally sound basis was formulated. Notwithstanding, the policies for rainwater harvesting differ among the mountain states of India (Volume 2,Chapter 3). The National Water Policy is general and does not deal with water harvesting in specific areas. As the water sector is on the State list, states have formed their own policies on water harvesting. The Government of Himachal Pradesh has recently issued a notification making harvesting rainwater mandatory for drinking and domestic purposes in all new constructions and existing buildings in the state.

In **Nepal** the Ministry of Housing and Physical Planning published a National Policy on Drinking Water Supply in 1998. There is no separate policy for rainwater harvesting and use. The 9th plan of Nepal has pointed out that, in remote areas where viable sources of drinking water are not available, harvesting and using rainwater will be promoted. However, there is no specific policy for harvesting rainwater (Volume 2, Chapter 4).

In **Pakistan**, there is no specific policy on water harvesting. However, in Balochistan substantial subsidies on pumps and electricity have had an adverse impact on groundwater levels. There is a national water development policy, but it does not specify rainwater harvesting (Volume 2,Chapter 5).

CASE STUDIES

Chapters 6 to 11 in Volume 2 cover case studies in particular areas of the countries for which policy reviews were carried out. These case studies review local water-harvesting practices and were presented at the workshop. The break down is as follows—not necessarily in chapter sequence but rather according to a mix of geographical area and climate.

There were two case studies each from India, Nepal, and Pakistan. Three case studies were from relatively wet areas – where rainfall was above 1,000 mm per annum. In **India** a watershed in the **Tehri Garhwal** district of **Uttar Pradesh** (Volume 2,Chapter 6) was examined; in **Nepal**, **Kabhrepalanchok** (Kabhre) district lying directly east of Kathmandu was the site (Volume 2,Chapter 7) In **Pakistan** a small watershed in **Mansehera** district in the **North West Frontier Province** (NWFP) was covered (Volume 2,Chapter 8). In terms of elevation, all three were located at lower altitudes (i.e., below 1,500 m). Rainfall decreased from east to west throughout the HKH region and based on this one could conclude that Balochistan (Pakistan) in the west was much drier than Kabhre (Nepal) in the east. The three others case studies were from relatively dry areas with desert-type conditions: **Ladakh** (in north **India**); **Mustang** in central north **Nepal**, and **Balochistan** (in **Pakistan**), (both the former being in the rainshadow (Trans-Himalayan) — and hence classifiable as cold deserts (Volume 2, Chapters 9, 10, and 11).

In general, all the case studies noted that less difficulty was encountered in harvesting drinking water. Drinking water supplies for both people and livestock had so far been sufficient and could be collected quite easily. However, in all the study areas, women had to spend a lot of time fetching drinking water.

On the other hand, there were major problems in all areas regarding water supply for irrigation. The problems differed in nature as well as in severity from case to case. Most water-harvesting systems focussed on meeting irrigation needs, and this was where there were complex institutional arrangements for ensuring sufficient water in critical planting seasons.

The **Tehri Garhwal** case study area identified many interesting practices in local water harvesting, and these included the use of plants for purifying water and the separation of water sources for different social groups. While there has been a significant expansion in the use of modern systems (including the use of lift pumps to supply water), traditional systems were still very important for most of the people in the watershed (Volume 2,Chapter 6).

The case study area from Nepal's middle hills was about an area east of Kathmandu in **Kabhre district** (Volume 2,Chapter 7). There appears to have been many interventions in the past to improve local water-harvesting systems, for both drinking and irrigation. The most recent case of community involvement in water harvesting was the establishment of a micro-hydro electricity plant for which a fairly elaborate community organization had been put in place. External resources played an important role in various interventions. The main issue appeared to be the need for an increase in local resources to support present and future water-harvesting activities.

The unique feature of the **Mansehra** case study area was that it had neither an informal nor a formal community-organized water distribution system. Although group involvement in various water-harvesting activities occurred in Mansehra, decisions about quantities of water to be used and when and how to use it were made by the person controlling the water source. Those living upstream considered it their right to irrigate their fields first. If there was any excess water, then downstream households could irrigate their fields. Upstream farmers could divert any amount of water to their fields at any time they wished. This practice has given rise to an inequitable water distribution system. This has forced downstreamers to adopt cropping systems that need less water. Some farmers have been forced to leave their lands fallow (Volume 2, Chapter 8).

The **Ladakh (India)** case study area highlighted the existence of a fairly complex traditional institutional system for irrigation. There are many different systems extant and these vary from watershed to watershed. Given the limited growing season and the desert-like conditions, water supplies were used to maximise the area under irrigation. In short planting periods, water had to be distributed to the fields quickly. Individual decisions were confined to their own lands. Water allocation, distribution, and its supervision and monitoring involved a concerted effort on the part of the community. For a few weeks the entire community was mobilised to manage water distribution. The future of such systems was questioned not from the perspective of a failure in the technology of water harvesting, but because of the increasing difficulty in mobilising community members to participate in traditional water-harvesting systems (Volume 2, Chapter 9).

In the Trans-Himalayan area in **Mustang**, Nepal (Volume 2,Chapter 10), the institutional mechanisms for water harvesting were equally complex and well organized. Although similar to those found in Ladakh, there were also many variations. Interestingly, one point raised was that the prevailing system had not been modified or redesigned in spite of increased demands for irrigation arising out of the introduction of horticulture and tree farming. The priority in the prevailing irrigation system was for the production of cereal grains.

A highlight from the **Balochistan** case study area was that increased access to groundwater had resulted in greater sedentarisation of the community with substantial increases in income for those owning land and having access to groundwater. Sufficient supplies of water led to a reduction in seasonal migration, lessened the work of women compared to the previous nomadic lifestyle, and also resulted in an improved quality of life for the community. The main worry was the excessive mining of groundwater and its sufficiency in future. There were important questions about sustaining water supplies (Volume 2, Chapter 11).

CONCLUSION

The workshop concluded that water for domestic use, close to the household, was decreasing throughout the HKH region. Sustainable development of local water-harvesting systems was considered a promising method of providing water for domestic use in future. The workshop discussions evaluated the existing water-harvesting structures and social organizations in different mountain areas. The main recommendations focussed on the issues described in the following passages.

Integrating Indigenous Knowledge and Technology with Modern Practices

In order to improve and expand the practical applications of indigenous knowledge and technologies for sustainable water harvesting, planning, and management, research was needed. It was widely recognised that such technologies should be integrated into modern technologies. Specialised training at the local level, in the integrated application of traditional and modern technologies, was necessary.

Interdisciplinary Research and Increased Interaction among Stakeholders

It was recommended that research should be integrated and interdisciplinary, integrating bio-physical and socioeconomic concerns. The need for interaction among scientists, local people, and policy-makers during all phases of research and application was stressed.

It was also recommended that women should be trained and made responsible for operating and maintaining water-harvesting systems.

Empowerment and Institutional Development

Increased autonomy of local communities was necessary in order to involve them in all levels of decision-making. It was acknowledged that this type of empowerment was crucial for sustainable mountain development. This would enhance community responsibility for and control of local water resources and their development. It was agreed that institutional development was necessary at all levels — national and local for development and in management and coordination of water-harvesting plans and policies.

Regional Institutions and Cooperation

It was agreed that international involvement and regional cooperation were essential for sustainable water resource development. Cooperation in research, development, training, information exchange, sharing of experiences, technologies, and methodologies was essential.

It was recommended that guidebooks on water harvesting should be published in local languages (especially those translated from Chinese into English) and distributed to different mountain areas in the region.

There is a situation of acute water scarcity in most rural mountain households in the HKH region: it is a situation of scarcity amidst plenty. Water is not available where it is most needed. In the past, mountain households have displayed great wisdom in not only harvesting water but also in using it prudently. Today, this is no longer the case and water has become an important issue. It underlies the rampant poverty, deteriorating environment, and increasing communal disharmony. As the previously accessible sources of water disappear, communities are forced to harvest rainwater. The potential for harvesting rainwater is vast, and this was clear from the various discussions held. Finding efficient ways to use the water available will be a key factor in sustainable development of mountain areas. Harvesting and storing rainwater properly will be important components in future.

Chapter 2

Water Resource Management in the HKH: An Overview

Suresh R. Chalise

BACKGROUND

Extending 3,500 km from Afghanistan in the west to Myanmar in the east, the Hindu Kush-Himalayas (HKH) are home to nearly 150 million people and influence the life of more than three times as many in the downstream basins and plains. As the largest storehouse of fresh water in the lower latitudes, these mountains and the Tibetan plateau are important water towers for nearly 500 million people.They are also the sources of mighty rivers such as the Indus, the Ganges, the Yarlung-Tsangpo, the Brahmaputra, the Nu-Salween, the Yangtze, the Yellow River, and the Mekong (Map 1).

The Hindu Kush-Himalayas are often referred to as the 'Third Pole' as they contain the largest mass of ice and snow outside the earth's polar regions. The areas under ice and snow are located at the highest elevations on earth, with the permanent snow line at about 5,000 m. The mountain peaks of the HKH reach almost 9,000 m; the highest Mt. Sagarmatha (Everest), also known as Chomolongma, has an elevation of 8,848 masl. Many glaciers are found in the HKH, including some of the longest outside the polar regions (for example, Batura glacier in Karakoram, Pakistan). They provide a unique situation in which vast, perennial sources of water are available at elevations higher than elsewhere on earth. The hydropower potential of the rivers and streams is enormous and one of the greatest in the world. Altitudes change very rapidly within short horizontal distances: a feature that provides advantages as well as posing problems for water resource management in the HKH (Fig. 1).

The fact that water can be found at such great heights has made human habitation possible at some of the highest elevations on earth.Human settlements can be found even beyond 4,000 m (for example, Khopagaon in Dolpa district of Nepal, located at 4,300 m, is considered to be the highest permanent settlement and temporary/seasonal settlements, each with their own unique cultures and traditions, are found close to 6,000 m). People have survived at these high altitudes, practising pastoralism on the pastures above the treeline (about 4,000 m for the eastern and 3,000 m for the western HKH). They rear yaks, goats, and sheep. This has been possible because of the perennial supplies of water.

Map 1: Major River Basins in the HKH
(Source: Myint and Hofer 1998)

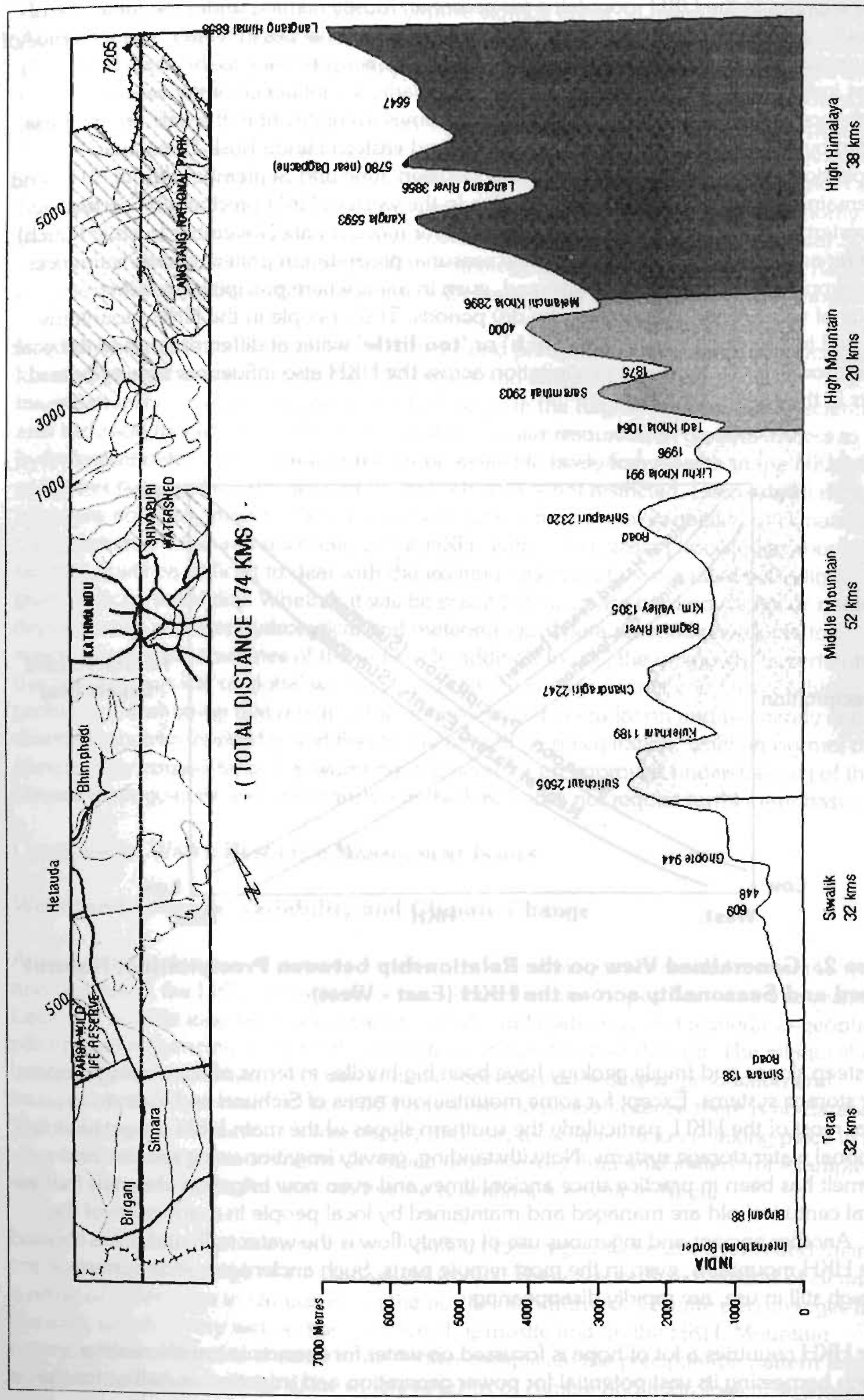

Figure 1. Cross-section of Central Nepal

Water supplies in the HKH mountains are seasonal, mostly coming under the influence of the south-west monsoon in summer and the western disturbances in winter. The influence of the summer monsoon is strong in the east and diminishes gradually to the west, being almost insignificant in the Karakoram region. Similarly, the influence of the western disturbances is predominant in the west and becomes insignificant in the east. In the areas affected by the monsoon, mostly in the central and eastern Hindu Kush-Himalayas, precipitation is confined to the four months between June and September (about 80%) and the remaining months are comparatively dry. In the western HKH precipitation caused by the western disturbances occurs mostly during four months (late November to early March) in winter and early spring. Such a marked seasonal precipitation pattern greatly influences water supplies from season to season and, even in areas where precipitation is intense, scarcity of water is common during the dry periods. Thus, people in the HKH mountains have had to cope with either **'too much'** or **'too little'** water at different times of the year. This seasonal characteristic of precipitation across the HKH also influences natural hazard events in the region (Fig. 2).

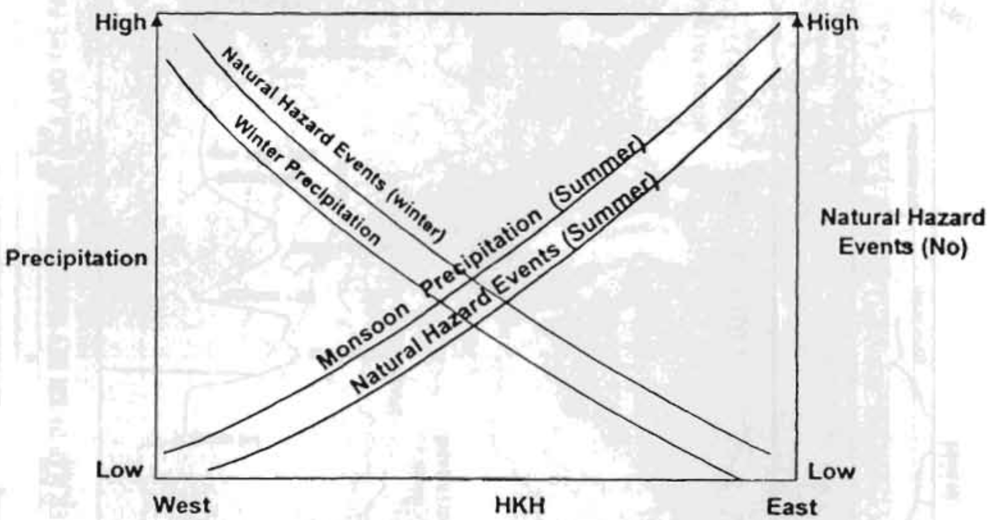

Figure 2: Generalised View on the Relationship between Precipitation, Natural Hazard and Seasonality across the HKH (East - West)

Very steep slopes and fragile geology have been big hurdles in terms of developing proper water storage systems. Except for some mountainous areas of Sichuan and Yunnan in China, most of the HKH, particularly the southern slopes of the main HKH range, have few traditional water storage systems. Notwithstanding, gravity irrigation using streams and snowmelt has been in practice since ancient times and even now irrigation channels that are several centuries' old are managed and maintained by local people in many parts of the HKH. Another ancient and ingenious use of gravity flow is the water mill, and these abound in the HKH mountains, even in the most remote parts. Such ancient irrigation systems, although still in use, are rapidly disappearing.

In the HKH countries a lot of hope is focussed on water for economic transformation through harnessing its vast potential for power generation and irrigation as well as for the control of floods by constructing multipurpose storage dams on mega and small scales. **According to the estimates available, the total theoretical power potential of the HKH countries (not including Afghanistan) is nearly 429,000 MW** (details and country breakdowns are given in Annex I of this paper). This is a substantial amount and naturally raises high hopes in the Region. Although mega projects for power, irrigation, and flood control were preferred in the past and are still priorities in many countries (e.g., the Three Gorges' project on the Yangtze River in China, Pancheswar/ Mahakali in India and Nepal, and Tehri in India), there is a growing and active campaign to shift the priority to 'small' projects. This campaign has arison out of concern about the environmental consequences of 'mega' projects, the fragile geology and active seismicity of the Region, and the costs of big projects that are normally beyond the means of the HKH countries.

In addition, the extreme variability of climatic and precipitation patterns, the paucity of knowledge on the hydrology of the HKH rivers and streams, and the complex interrelationships between ecology and hydrology in the Region impose serious scientific and technical limitations on the development of water resources. In general, access to hydrological data is restricted and not made available freely for research in the HKH; the exception being in Nepal where access to such data is not restricted. Even spatial data and maps are not easily available for researchers. Again, the normal variability of climate and precipitation is wide and uncertain in the HKH. Without increasing knowledge about the climate, it will be difficult to deal with the exciting 'uncertainty' associated with climatic (and precipitation) variability. Whether it will be possible to increase our knowledge or not will depend upon whether hydrological and meteorological data are made available to researchers by the countries of the region. In addition to this, the unknown 'uncertainty' of the possible impacts of global warming and climate change further complicates this problem. Considering that much of the environmental degradation and frequently occurring disasters, such as landslides and floods, are caused by precipitation, whether normal or abnormal or caused by global warming, the need for an improved understanding of the climate-ecology-hydrology relationship in the HKH does not require further emphasis.

Overview of Water Resource Management Issues

Water and Climatic Variability and Climate Change

A proper understanding of climatic variability and hydrological characteristics of the rivers and glaciers of the HKH is essential for translating the high 'hopes' for water into reality. Lack of a reliable long-term database on climate and hydrology and related bio-geophysical parameters influencing them for the mountains makes this task difficult. The relationship between human activities and hydroclimatic processes on sediment production and transport in the river basins of the HKH is not easy to assess because there is no database. This increases uncertainty in water supply and use, as sedimentation is taking place in the reservoirs of large dams in the region much more rapidly than anticipated; for example in the Tarbela reservoir in Pakistan and in the Kulekhani reservoir in Nepal.

Lack of a reliable database also makes it difficult to categorise climatic events and their impact on the hydrology of the Himalayan waters. There is a vertical zonation of climate as a result of differences in altitude along the north-south transect. Climate also changes from the east, which is very wet, to the west, which is mostly arid, in the HKH. Mountain topography and the rain-shadow effect further complicate the precipitation pattern and even adjacent watersheds can be differ widely in terms of climate and hydrological regimes. In addition to such diversity in climates caused by physical factors, there is also an inter-annual variability in precipitation and weather events. Hence, one can never ascertain whether any extreme weather event is a manifestation of normal climatic fluctuations or whether it is caused by abnormal conditions such as global warming and climate change.

The region has suffered major climate-induced disasters in recent years. Consecutive catastrophic monsoon floods occurred in Bangladesh during 1987 and 1988; there were floods in the Indus Basin in September 1992; a disaster was caused by floods and debris flows in south-central Nepal in July 1993; and there were floods along the Yangtze in 1995 and 1999. Relating these events to the impacts of climate change in any given pattern is difficult. It has been claimed that the Pakistan flood was caused by the changing strength and timing of summer monsoon incursions into the Trans-Himalayan region of the Karakoram. This was earlier considered to be an event that occurred every fifty years, although now it has been found to occur more frequently.

Systematic studies are yet to be carried out on seasonal snow cover in the HKH. However, snow and glacier studies have received a lot of attention in many countries of the region. Most of the studies indicate that glaciers are retreating. A serious implication of glacier retreat is the possible increase in Glacial Lake Outburst Flood (GLOF) events in the region. Mayewski and Jeschke (1979) have made local and regional syntheses of 112 records of such fluctuations in the HKH. Their study shows that the glaciers in this region have been in a general state of retreat since AD 1850. Reports of glacial retreat and accelerated ablation have also been given in Nepal. On the other hand, in the Karakoram and Kunlun mountains, both advancing and retreating glaciers have been reported.

It is difficult to determine the significance of these fluctuations in terms of global warming, although they indicate some kind of change in climatic pattern, and this has implications for managing and developing water resources in the region. Although a proper assessment of the potential impacts of global warming and climate change in the HKH region has yet to be made, it can be inferred from the Intergovernmental Panel on Climate Change (IPCC) Impact Assessment (Houghton *et al.* 1990) that, as a consequence of climate change, the HKH region will, in general, witness increased monsoon rainfall, increased precipitation, and shrinking of areas under snow and ice and permafrost (Chalise 1994). Obviously such events induced by climate change would have serious implications for food production; power generation; water supplies, particularly during the lean (dry) period; and on the frequency of natural hazards (floods and landslides) in the HKH.

Transboundary Nature of Major River Systems and Problems in Information/Data Exchange

Apart from the Yangtze, and the Yellow rivers, most of the major rivers of the HKH (the Indus, the Ganges, the Yarlung-Tsampo-Brahmaputra, the Nu-Salween, and the Mekong) originate in one country and traverse through other (one or more) countries before reaching the ocean. The catchment areas of these rivers, therefore, extend beyond the boundaries of one nation. Despite these realities dictated by nature, countries in the HKH do not share hydrological data as a rule. In many countries of the HKH, hydrological data and even spatial information and maps are classified and not available even for their own national researchers. There are, luckily, a few exceptions. There is an agreement between India and Pakistan on the Indus (its tributaries), data are exchanged between China and Bangladesh on the Brahmaputra, and hydrological data are openly available in Nepal. By not sharing hydrological data, the growth of knowledge on the hydrology of the region has been adversely affected and consequently the pace of development of water resources in the region. Sharing hydrological, climatological, and spatial data is a prerequisite for optimum use and management of regional waters in order to provide full benefits to the people from this rich resource. Some regional initiatives have been taken in this respect through the recently launched Hindu Kush-Himalayan Flow Regimes from International and Experimental and Network Data (HKH-FRIEND) project. HKH-FRIEND is a part of the global FRIEND project of UNESCO's International Hydrological Programme (ICIMOD/ UNESCO-IHP 1999 a and b). The costs of the 'lost opportunities' in hydropower generation, in irrigation development, and in flood control are enormous, at both national and regional levels.

Regional Cooperation in Sustainable Development and Management of Water Resources

Regional cooperation in the development and management of water will help to realise full benefits from various water resource development projects at both national and regional levels. Except for India and China in a few cases, for most of the countries of the HKH, realisation of full benefits from their resources will entail cooperating and sharing with neighbours. This is particularly true for **'headwater countries'** like Afghanistan, Bhutan, and Nepal. Similarly, **'downstream countries'** like Bangladesh, India, and Pakistan, are dependent on their upstream neighbours for developing effective flood control and irrigation systems as well as for augmenting water supplies during lean periods. For the HKH countries, regional cooperation for optimum development and use of water resources is an imperative dictated by the geography of the region. Such cooperation alone can ensure that 'lost opportunities' are transformed into real benefits.

Ecohydrology of the Region and Water-induced Disasters

Because they are the most recently formed mountains on earth, the Hindu Kush- Himalayan ranges are tectonically active and hence inherently vulnerable to hazards. They are also exposed annually to intense, seasonal precipitation during the four months (June - September) of summer monsoon, particularly in the eastern areas. This acts as a trigger for natural hazards at different elevationss. If snow avalanches and glacial lake outburst floods predominate at very high elevations (>3,500 m), then landslides, debris flows, and flash floods are common in the middle mountains (500-3,500 m). Floods are the principal hazards in the lower valleys and plains. During extreme weather events, the consequences are disastrous. Hundreds of lives and billions of dollars' worth of property and investments in infrastructure are lost in the region every year. Landslides, debris flows, and floods also destroy scarce agricultural lands. In China, for example, landslides alone are estimated to cost US$ 15 billion and cause 150 deaths annually (Li Tianchi 1996), and in Nepal landslides and floods destroy important infrastructure worth US$ 2.5 million and about 400 deaths annually (Khanal 1996).

Despite climate and hydrology being the principal causes of and contributing factors to natural hazards in the HKH, they have received insufficient attention. Management of hazards and disasters in the HKH will not be possible without effective management of water (ICIMOD 1997), and this too has received insufficient attention.

Much of the discussion about environmental degradation in the HKH which started in the mid -70s focussed primarily on ecological concerns, particularly on deforestation caused by rapidly growing human and animal populations and the impacts on local and regional ecology and economics, particularly erosion and sedimentation. Since then, most research work, whether field-based or based on available data, has focussed on in quantifying the relative roles, impacts, and contributions of human and natural processes in causing environmental degradation in the region. However, the impact of climatic processes, particularly intense rainfall events of short duration, on the ecology and on environmental degradation has not received sufficient attention. A recent study demonstrates that human processes are more important for micro-basins, whereas natural processes predominate in macro-basins. It has also demonstrated that without a better understanding of the processes occurring on the meso-scale and the linkages between these processes on different scales, it will not be possible to ascertain the actual roles of human beings and Nature (Myint and Hofer 1998).

Pollution of water bodies, both surface and groundwater, is another problem that is growing rapidly, not only in urban areas (where it is mainly due to mismanagement of sewage and domestic and industrial wastes) but also in rural areas (where it is mainly due to indiscriminate and uncontrolled use of pesticides and chemical fertilizers) of the HKH. Although comprehensive studies are yet to be carried out, data from selected areas of the HKH show that deterioration in water quality is quite alarming, particularly in small rivers, streams, and shallow groundwater. This has serious implications for poor and marginalised people in both urban and rural areas, because they are dependent for water supplies on openly accessible water bodies such as rivers, streams, and shallow wells and springs.

Water for Mountain Households

The population of the HKH Region, which extends over an area of 3.4 million square kilometres across eight countries, from Afghanistan to Myanmar, is growing rapidly and with it the demand for water. The current population of nearly 150 million is expected to double within the next thirty-five years and hence the demand for water will increase tremendously within the next few decades, particularly because the pace of development is accelerating in all the countries of the region. Changes in life style, with greater consumption of water at individual household level alone, will create huge demands for fresh water in the region. Similarly, food production through increased use of high-yielding varieties of crops will mean additional and dependable supplies of water for irrigation; water supplies will have to be much greater than they are at present.

Recently the use of pumps (electric, or diesel) and PVC pipes for water supplies has increased in the rural mountains. Although this has reduced the drudgery of fetching water from long distances for women and children in some areas, most rural mountain communities are still left to their old methods of procuring water for domestic and agricultural needs. There are practically no data and information on water quality at local sources. It is an important challenge to combine modern methods and techniques with indigenous knowledge and traditional institutions for local water management: and such institutions are unfortunately disappearing (Agarwal and Narain 1997)

Human Capacity and Status of Research

Research skills and the state of research on water resource development and hydrology vary a great deal in the HKH countries.

So far, there is no institution established by the regional countries for research and training in water resource development. There are, nevertheless, institutions (particularly in India and China) that have been either sponsored by UNESCO or run by UNESCO-sponsored programmes for regional training and research on water resource development, hydrology, and related fields. The Water Resources' Development Training Centre in Roorkee, India, and the International Centre for Research and Training in Erosion and Sedimentation in Beijing, China, are among such institutions. A South Asian Association for Regional Cooperation (SAARC) Meteorological Research Centre, now located in Dhaka, Bangladesh, has begun functioning recently.

Sustainable development of water resources to the fullest extent possible depends not only on knowledge of engineering but also on an adequate understanding of the hydrological behaviour of water sources and its environmental consequences. Hydrology of water resources in any particular region is principally characterised by the climate and partially by local geology, topography, and land use (including agriculture and other economic activities affecting water). Unfortunately, as already stated, knowledge of hydrology of HKH water sources is limited, and most of the methods developed in entirely different climatic, geological, topographical, and land-use conditions of Europe and North America that are used in the HKH in the absence of reliable, regionally developed methods of hydrological analysis, assessment, and modelling are not entirely suitable.

In terms of scientific issues related to water resource development in the region, priority areas for research and training in the short term should include the following.

a) Management and optimum use of local water resources for and by the local people: water harvesting and water quality assessment at the local level
b) Development of appropriate methods and application of modern engineering and computer- based methods, technologies, and tools (including Remote Sensing and GIS) for hydrological regionalisation and assessment of and decision-making about water resources (big or small) for different uses (irrigation, hydropower, and so on)
c) Hydrometeorological database management
d) Management of water for disaster prevention and hill and slope stabilisation (for example, floods, GLOFS, landslides, and debris flow control and management).
e) Water laws and conflict resolution at local, national, and regional levels
f) Impact assessment of water resource development projects, particularly big and multi-purpose projects
g) Glacier and snow cover monitoring (field-based as well as by using remote sensing/ satellite data)

REGIONAL TRENDS

Water as 'Hope' for the Future

In some countries of the HKH, water has caught the imagination of the people as 'hope' for the future (Verghese 1990). It is seen as a national endowment that, through regional cooperation in water resource development for power, irrigation, and flood control, can do much to improve the standards of living and circumstances of the people of the HKH. However these expectations have been elusive. Such 'hopes' can be realised only if the countries concerned are willing to cooperate and take action. Some of the prevalent myths and expectations need to be reviewed and examined in the light of fresh evidence. For example, there is a widely held 'myth' that regular floods in Bangladesh are due to the Ganges overflow from India and Nepal. However, it has been shown that it is Meghalaya and not the Himalayan waters that are responsible for such floods (Hofer and Messerli 1997). A chain of high dams in the headwater regions of Nepal and India has been envisaged as a panacea to solve the problem of floods downstream and to provide water for irrigation and power during the lean (dry) period. Yet, considering the fragile and hazardous nature of environments in the headwater regions of Nepal and India, the 'new uncertainty' concerning the possible impacts of global warming and climate change, and the continuing uncertainty about the impact of people and nature on the quantity and quality of water flowing out of mountain watersheds, how realistic are these 'hopes'? This question should be examined on scientific and technical grounds. There are also differences in perception in the political circles of the regional countries about the way water resources should be developed and managed. Hence a lot of ground work has to be undertaken on scientific, technical, and socioeconomic aspects of regional waters before 'hopes' can really be translated into realities.

Water, Women and Basic Rights of the People

In all the countries of the HKH, governments are finding it difficult to meet the basic needs of the people; and this is an increasing concern. Basic needs include safe drinking water not only in urban areas but also in rural areas. Many international programmes, such as the International Decade for Drinking Water and the Dublin conference (1992), and the growing awareness of people about their basic right to have access to safe water have contributed to increased awareness at all levels and renewed commitment on the part of governments.

Many rural mountain households in the HKH do not have access to adequate supplies of safe water as yet. The use of polythene pipes and cement-lined storage systems, however, is increasing; and these new materials and systems have alleviated the problem of water scarcity and reduced the drudgery for women to some extent. However, much more needs to be done, particularly in terms of ensuring that women and children do not have to travel long distances for water in the rural mountains and hills of the HKH.

Water as an Economic Commodity

A key shift in the global perspective on water is to cease considering it as a free gift of nature but rather to consider it as an economic good or commodity. The 1992 Dublin Conference clearly enunciated this. Other international water programmes, including those of UNESCO, have emphasised this point recently. However, the perception of the average mountain dweller in the HKH is still traditional in this respect and water is still seen as a free gift of nature. With gradual incursion of the market economy, even in remote mountain areas, changes in this traditional perspective are becoming visible. Similarly, the possibilities of using water for power generation and using locally-generated power for economic activities or directly to produce high-value, off-season vegetables or cash crops have increased awareness about the economic value of water amongst local mountain communities. It is also true that, whereas, traditionally, conflicts about water among neighbours or neighbouring communities were related to survival issues, such as drinking and irrigation, more recently conflicts tend to be related to other uses such as hydropower generation and diversion of water from one watershed to another.

Integrated Development and Management of Water

The recent emphasis on sustainable economic development has encouraged thinking in terms of sustainable management of water on a holistic basis, taking into consideration its relationship with other natural resources as well as with other natural and human processes: processes that affect the quality and quantity of water in terms of long-term supply. People-oriented sustainable economic development has now become, more or less, a global aim and objective. This perspective has received due priority and consideration in all the countries of the HKH. This perspective was not there in the 1960s and 70s when governments did not hesitate to move people from project sites. Governments also failed to consider the impacts of such projects on the local ecology and on aquatic life (for example, the Bhakhra-Nangal in India, Tarbela and Mangla in Pakistan, Kaptai in Bangladesh, and the Koshi, Gandaki, and Kulekhani in Nepal). The Chakma problem in Bangladesh owes its origins to the construction of the Kaptai dam, and the Koshi Barrage in Nepal could not deliver the promised benefits as erosion problems were ignored. Yet, recently, the Arun Project in Nepal and the Tehri Project in India have been either abandoned or have had to face public and judicial trials on the grounds of their negative impacts on local communities, their cultures, and the local ecology and environment. In the contemporary world, there are also extreme cases in which older dams are being destroyed on ecological grounds (for example, dams on the Columbia River in Canada in order to save the salmon) and new giga projects and dams are being planned or constructed such as the Three Gorges' project in China (on the Yangtze) and the Tehri project in India; both of which are controversial.

Concerns should not only be limited to the development of water for power and/or irrigation, no matter how attractive economically, but it should also focus on development and management with a holistic and integrated approach. People-centred sustainable development of water resources that takes into consideration interlinkages with other resources, sectors, and processes (physical, biological, and human) within a basin is the most important priority.

The 'Big' versus 'Small' Debate

As elsewhere in the world, the 'big' versus 'small' debate is growing even about water resource development projects in the HKH. The main issues with regard to mega-scale projects and in favour of 'small' projects in the region are as follow.

- Impact on the lives and culture of the local people
- Environmental and ecological impacts of projects
- Absence of long-term hydrological and climatological data for planning and design
- Inadequate knowledge about the climate and hydrology of major basins in the HKH (particularly about extreme weather events, their rates of return, and their impacts on hydrology and sediment generation and transport)
- Uncertainty about the possible impacts of climate change
- Risks associated with the inherent seismicity of the region
- Inadequate knowledge about dam-induced seismicity related to mega projects
- Inadequate knowledge about the impacts of nature and people on mountain watersheds and on varying scales (macro, meso, and micro) and the impacts on the quantity and quality (physical as well as chemical) of out-flowing waters
- Lack of human capabilities, such as technical skills and financial resources, in the countries of the HKH (with the exception, perhaps, of China and India) for planning, designing, and implementing mega projects

- Related to the former—total dependency on external capital and technical know-how without taking long-term local and national interests and priorities into consideration and even discouraging local and national initiatives in this sector in future

'Small' projects, on the contrary are considered better than big ones as they can be planned and executed, both financially and technically, by the countries themselves without too much dependency on external factors. They are also considered to be more environmentally and ecologically friendly; less threatening to local people and their culture; less risk in terms of planning, designing, and managing with limited data; and more responsive to local and national interests and priorities.

Transboundary Water Issues

As mentioned earlier the main rivers in the region are transboundary in nature, as they originate in one country and traverse through one or more countries before they reach the ocean; with the exception of the Yangtze which lies entirely in China. Almost all the major rivers of the region (viz., the Indus, the Ganges, the Yarlung-Tsangpo-Brahmaputra, the Mekong, the Nu-Salween, and the Yangtze all originate in Tibet and pass through different countries before reaching the ocean. Hence, it is a practical necessity that, for realistic planning and to derive full benefit from such rivers, closer dialogue and collaboration on the use of such river waters should be established. The important transboundary issues related to river waters in the HKH are as follow.

1. Control of floods—including glacial lake outburst floods
2. Planning and management of large-scale water resource development projects (single or multipurpose) on transboundary or border rivers and sharing of water and benefits (mainly for irrigation, power, and flood-control)
3. Management of upland watersheds/sub watersheds of the major river basins from a longer-term perspective.
4. Large-scale collection and storage systems in headwater regions (countries) to ensure supplies during lean periods for both upstream and downstream areas within a country or even outside in a neighbouring country
5. Conservation and use of regional aquatic resources, particularly riverine aquatic resources, in consideration of the potential impacts of future development of water resources on their migration and survival

CONCLUSION

Water in the HKH also provides a unique opportunity for regional cooperation in which each partner will gain net benefits and no one will really be the loser. A lot of ground work at both political and technical levels is still needed to ensure that the full advantages of this opportunity provided by nature are realised.

There are clear indications that a crisis is building up in the HKH in the context of the sustainable management of water resources. The following are contributing to this crisis.

1. The rapidity with which the population is growing
2. The rapidly-changing consumption pattern with increasing demands for water and other natural resources
3. The breaking down or growing irrelevance of traditional social, economic, and technological systems and indigenous knowledge

4. The rapid depletion of the natural resource base through internal and external pressures
5. The inadequacy of knowledge about the natural processes that govern the natural environment
6. The uncertain but possible impacts of global warming and climate change

Already there is increasing evidence of glacier retreat and decrease in snow cover in many parts of the HKH. These could affect water supplies, particularly the low flows of even perennial rivers, during lean periods if such trends of rapid deglaciation continue.

If the crisis is to be averted, future research programmes will have to take into account these factors in order to develop the ability to respond to the challenges. Obviously it is a complex problem, and solutions are not going to be simple or easy to find. It is also clear that, irrespective of all the existing unknowns and uncertainties with regard to water resource development, massive investments are being made or will be made in the region in water resource development projects for power generation, irrigation flood control, and urban supply. Whether such investments will bring the returns estimated will depend on how reliable and adequate our knowledge is and how quickly we can develop knowledge on hydrological responses to 'normal' and 'abnormal' (due to global change) impacts of the climate in the HKH (Chalise 1998).

Another extremely important issue deserving the immediate attention of the governments of the HKH countries is reorientation of water policies. Without such reorientation the water supply problems of rural and marginalised mountain farmers will not be solved. The water needs of poverty-stricken people living at high altitudes are particularly critical as traditional sources of water are either insufficient to meet the present needs, even for drinking water, or have dried up and no longer yield water. Insufficient winter rains and an increase in the dry period, leading to drying up of local springs and small perennial streams, have been observed and experienced by mountain people in recent years throughout the HKH. Contrary to the popular belief that the drying of local springs and other water sources is linked to local deforestation, it appears that poor winter precipitation (rain or snow) is the principal cause of water scarcity in the hills and mountains of the HKH. This issue has not been studied systematically as yet.

The fundamental need is to provide water to the people in the hills and mountains who are totally dependent on rainwater or snow for water supplies for drinking or for other domestic and irrigation needs.So far, national water policies in the HKH countries have focussed on large-scale projects for power irrigation, flood control, and urban supplies, providing benefits mainly to the people living in urban or plain areas. The water supply problem in the mountains has already reached crisis proportions in many parts of the HKH. Thus scarcity of water adds to the already miserable economic circumstances and mass poverty that cause the constant outmigration of able-bodied men from mountain areas. There is an urgent need to avert such crises by introducing water harvesting, collection, and storage systems at the household and local community levels with people's participation.

A major policy shift is needed in water resource development in the HKH countries. It should take care of water supplies for mountain households. It has been already seen in China that a favourable policy promoting water harvesting and storage systems managed by the people at household level on a mass scale can transform the economy in poverty stricken areas within a very short time (Chalise *et al.* 1999). A similar approach would also benefit mountain people in other countries of the HKH. Guaranteeing domestic water supplies will lead to a sustainable improvement in the quality of life.

Table Annex I: Hydropower Potential in the Hindu Kush-Himalayas

Country	Total Hydropotential	Total Installed Capacity
Afghanistan	NA	292 MW (1)
Bangladesh	1500-2000 MW (2)	232 MW (1)
Bhutan	20,000 MW	342 MW (1)
China		
(a) Tibet : Yarlung-Tsangpo (Upper Brahmaputra)	110,000 MW (4)	NA
(b) China (whole country)	NA	30,100 MW (1)
India		
(a) Indus	19,998 MW (5)	2570 MW (5)
(b) Ganga	10,715 MW (5)	1,675 MW (5)
(c) Brahmaputra	34,920 MW (5)	288 MW (5)
(d) India (whole country)	84,000 MW (5) at 60% load factor	14% of total potential harnessed
Myanmar	108,000 MW (6)	267MW (1)
Nepal	83,280 MW (7)	235 MW (1)
Pakistan	40,000 MW (8)	2,897 MW (1)

Note: Total Installed Capacity (TIC) figures for all countries apart from India are for.. 1990. For India, the figures are for 1992.

Sources: (1) UN, 1992; (2) Shahjahan, 1983 as quoted in Bandyopadhyay and Gyawali, 1992; (3) RGB.PC (1991); (4) Guan and Chen 1981; (5) CWC 1992; (6) Burma 1983; (7) Gyawali 1989; (8) SHP 1991. Refer to Chalise *et al.* 1993

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Chapter 3

Water Policies and Local Water Harvesting in the Hindu Kush-Himalayas[1]

Prachanda Pradhan

INTRODUCTION

Water stress is being experienced in many countries. Hindu Kush-Himalayan (HKH) countries have severe problems because of scarcity of water. Harvesting rainwater and water from other sources by people and agencies for different purposes is in practice in the region. Over a period of time, different methods of water harvesting, ranging from collection and use of rainwater to groundwater, stream to river water, and even flood water storage, have been developed in different parts of the HKH. It is proposed to focus in this paper on policies relating to rainwater harvesting.

In some areas, deliberate efforts are made to harvest rainwater; in other areas, it is difficult to find specific efforts to harvest rainwater. In the absence of a specific policy on water harvesting, traditional water-harvesting technologies have been neglected in some countries, resulting in added hardship in getting sufficient water. In other cases, specific policies were introduced to support rainwater harvesting and make water easily accessible for domestic use as well as for economic activities. Hence, it is important to understand both the existing traditional technologies for water harvesting and the involvement of local institutions, people's organizations, and civil society in promoting water harvesting within the broader policy context of addressing the challenges of water stress in the Hindu Kush-Himalayan Region.

This paper is a synthesis of the policy papers prepared by country experts from China, Bhutan, India, Pakistan, and Nepal and presented at a workshop in March 1999 (Changming Liu and Li Cheng 1990; Sarvanan 1999; Zia and Husnain 1999; Tshering 1999; IIDS 1999). In this synthesis paper, the focus is on water-harvesting issues in these five countries of the Hindu Kush-Himalayas. These policy issues include the specifics of policies for water harvesting in hardship areas and by the poverty-stricken population of mountain regions where there is a close relationship between water scarcity and the high incidence of poverty. The other component of the policy aspect is the promotion of new technologies and preservation of traditional water-harvesting technologies. Financing the implementation of water-harvesting systems and methods of implementing water-harvesting

[1] Changming and Cheng 1990; Sarvanan 1999; Zia and Husnain 1999; and Tshering 1999

programmes are other aspects of policy issues. Policy formulation on water harvesting by the governments of the HKH is now to be oriented towards poverty alleviation in these areas. In this context, the role of the government is to be reviewed.

The policy aspects in the papers presented at the workshop will be examined from four perspectives. They are the (a) overall policy aspect, (b) technological aspects, (c) financing aspect, and (d) implementation of the schemes.

FOCUS OF THE AREA AND DESCRIPTION

Populations in the mountain areas of the region are growing rapidly (Table 1). Water, like land, is becoming a scarce resource in the Hindu Kush-Himalayan Region. The distribution of precipitation is uneven: high concentrations during monsoon with a prolonged dry season for the remaining period. Water shortages have increased proportionately with agricultural intensification, and the problem is so pronounced that water-harvesting methods have to be explored. Micro-catchment storage systems have been used successfully in several countries. Water scarcity is widespread throughout the high mountains, because of their low capacity for water retention. So water harvesting is necessary to solve the problem of providing sufficient water supplies for human consumption, farming, and livestock. The need for water harvesting is growing rapidly in the whole arid and semi-arid areas of the region.

Table 1: General Description of the Study Region

Name of the Country	Total Pop. (in millions)	Total Area (sq.km.)	Mountain Area (in %)	Pop in HKH Area (in millions)	Density of Pop (per km^2)
China	1232.1	9607000	70%	30.45	13
Bhutan	0.6	40500	100%	0.6	15
India	939.42	3287263	14%	41.16	89
Pakistan	134.15	796095	61%	31	63
Nepal	21	147181	60%	12	147

Sources: Changming Liu and Li Cheng 1990; Sarvanan 1999; Zia and Husnain 1999; Tshering 1999; IIDS 1999

The sources of water in these regions are rainwater, glaciers, rivers, and groundwater. However, easily available water resources are only glaciers and rainwater. The important task is to adopt a technology that can harness these resources for the benefit of the households in the region. In the HKH countries, there are experiences of promotion and preservation of water harvesting. These experiences can be learned from and their relevance in the context of the overall rainwater harvesting policy assessed.

POLICY ASPECTS

Water harvesting and conservation have to go together. Water harvesting and protection of water bodies should become important components of national water policies. National water policies along with specific water policies for areas where there is hardship caused by water stress should be evolved through national-level dialogues and debates involving NGOs, local-level communities, national experts, and stakeholders. The following section will highlight the evolution of water-harvesting policies in the HKH. The following table (Table 2) gives an overall picture of the scope of water-harvesting policies.

Table 2: Policy Aspects of Water Harvesting in the HKH Countries

Items \ Country	China	India	Pakistan	Bhutan	Nepal
WH Policy	*	-	-	-	-
General Water Policy	*	*	*	*	*
WH at HH level	*	*	-	-	-
Policy with Investment	*	-	-	-	-

* Policy exists
- No specific policy exists

In Bhutan, there are no specific policies on water harvesting. However, there are guidelines for water harvesting for irrigation and drinking water.

Regarding irrigation development, the Land Act grants permission to harvest water for irrigation provided that the person doing so does not cause damage to others' land, house, or plantation. Use of water, which is jointly harvested, is to be shared among the beneficiaries of the system either by mutual understanding or by existing practice. There is no formal policy to guide the development of the drinking water policy. However, the rural water supply and sanitation unit of the Health Division has provided several guidelines to facilitate their activities. The overall goal of this programme is to improve public health by reducing the incidence of water borne and filth borne diseases through provision of safe drinking water and adequate sanitation facilities.

Mountain regions in China account for 70 per cent of its territory. Water scarcity is prominent in these areas. Water scarcity coincides with a high incidence of poverty as well. The Chinese Government places importance on water harvesting and has introduced many relevant policies for water harvesting.

Water harvesting in mountain areas received priority. Investments were made in water-harvesting projects. The national policy of China addresses the problem of poverty through water harvesting and ensures that water is supplied for domestic use as well as for agricultural purposes. Since 1984, a specific policy on poverty alleviation was introduced and one of the methods of addressing poverty is water harvesting.

In India, the National Water Policy of 1987 is a landmark in water sector development. The policy for the first time aimed at planning, developing, and conserving scarce water resources on an integrated and environmentally sound basis. However, there are different policies on rainwater harvesting among the mountain states of India. The National Water Policy is a general one and it does not focus on water harvesting in any specific area. Since the water sector belongs to the state list, different states have provided specific water-harvesting policies. The government of Himachal Pradesh has recently decided to make rainwater harvesting for drinking and domestic use mandatory for all new constructions and existing buildings in the state. Tamil Nadu has a similar policy.

In Nepal the Ministry of Housing and Physical Planning published a National Policy on Drinking Water Supply in 1998. There is no separate policy for rainwater harvesting and use. It is mentioned in the 9th plan of Nepal that, in every remote area of Nepal where alternative viable sources of drinking water are not available, rainwater harvesting and use will be practised. However, there is no specific policy as such for rainwater harvesting.

In Pakistan, there is no specific policy for water harvesting. However, in Balochistan the promotion of one type of water harvesting technology by means of a substantial subsidy on pumps and electricity caused an adverse impact on groundwater because of contradictory government policies. This situation refers to the case of Balochistan. There is a national water development policy, but it does not specifically highlight the policy on rainwater harvesting.

TECHNOLOGIES FOR WATER HARVESTING

The review shows that the technologies adopted by these countries are varied. Hence, attention is given to new, efficient technologies for water harvesting. In the meantime, it is also necessary to preserve already proven, traditional technologies for water harvesting. The following section describes the different types of water-harvesting technologies found in the HKH countries studied.

In Bhutan, gravity conveyance of water for agricultural use is common. The use of sprinkle irrigation and drip irrigation for water conservation is a recent innovation in some places.

In the past, the technology used by local people to collect drinking water consisted of split bamboo pieces laid end to end and supported on wooden stakes to form an open pipeline drawing water from a stream or a spring and carrying it to the settlement or to the households.

Another common technology was to simply dig a ditch in the ground and collect water from it for drinking. These days, polyethene pipes carry drinking water a long distance without loss of water.

In China, around the Yaluzabu Jiang River in Tibet, more than 5,000 water-harvesting stuctures were built.

In the Alpine region of Southwestern China, water harvesting technologies included (a) collection of rainwater from very small or small catchments, (b) extraction of subsurface flows, (c) digging wells to draw subsurface water or spring water, and (d) catchment of rain from the rooves.

Roof catchment collection in two cisterns or tanks known as the (1-2-1) rainwater-harvesting project was quite popular.

By 1996, rainwater collection cisterns numbered 5,25,600 units, bringing about a tremendous iimpact on the lives of the people, farming, and livestock productivity. The rainwater harvesting technology also included the pond construction, storage tanks, and sub-surface and surface water harvesting.

In Quinghai province , China, rainwater was collected in clay cellars. Later on, the clay cellar was replaced with brick cellars. Rainwater collected from the roof was used as drinking water. Rainwater collected from roads and the ground was used for irrigation. It is estimated that there are now about 400,000 cellars with a collective storage capacity of 11 million cubic metres.

Underground cisterns are suitable in the climatic conditions to overcome uneven distribution of rainwater. The cistern system is suitable for irrigating scattered farmlands and for provision to scattered households. It is suitable for investment from different sources. Users can also make provision for most of the construction of underground cisterns.

In India, rainwater tanks are used for collecting water in Himalayan villages, and they are used extensively.

- The people also practice roof-top water harvesting technology.
- The government promoted designs for water-harvesting structures that are based on permanency, and financial returns are being promoted.
- Moisture conservation through vegetative barriers is in practice on agricultural farms.
- Check dams and stream bank protection for water recharge are used in both mountain areas and the plains of India.
- Storage structures to capture runoff are used.
- Tree plantations to recharge groundwater and watershed management are other technologies.
- Small water ponds are constructed in the villages to capture rainwater.
- *Gul(s)* or irrigation channels to irrigate terraced fields are common in Himachal Pradesh.
- *Zing(s)* are common in rain shadow mountain areas.
- Man-made glaciers are used in Ladakh for agriculture and for drinking water.
- Bamboo drip irrigation is common in Meghalaya.
- Rooftop water harvesting is a community-evolved technology in Mizoram.
- *Kul* irrigation is common in Himachal Pradesh. The community-evolved technique is to divert melting water from glaciers to a village tank. This tank water is shared among the users through allocated water rights.

In the hills and mountains of Nepal, ponds were dug in the past to collect rainwater mainly for livestock use. Recently, different technologies were tried out to evaluate their use. They are being tried out by both government projects as well as by NGOs.

- Plastic-lined tanks for small irrigation activities (SAPPROS) and (INSAN) are being promoted.
- At household level, ferro-cement jars with a capacity of two cubic metres are used to collect water harvested from corrugated, galvanised iron sheet (CGI) rooves in Gulmi and Palpa districts.
- Ferro-cement tanks for use in rural water harvesting are being promoted by Peace Corp Volunteers

In Pakistan, the water-harvesting methods developed for agricultural purposes in the mountain regions are the diversion and dam systems. The diversion system is a long channel diverting floodwater to plantations adjacent to the valleys. The dam system is a large reservoir behind the dam filled with floodwater. The reservoir water is then pumped through pipes to numerous sprinklers that spread water to the winter crops.

In the *Rod Kohi* system, flash floods of short duration and greater magnitude hit the area generally during monsoon, some of the water is used by the local people in a traditional method of irrigation called *Rod Kohi*.

In Northern Balochistan, two of the main water-harvesting techniques used include building embankments and bunds to divert the stream and floodwater during the rainy season. It is called the *Sailaba* system in Balochistan. Another system is known as the *Khushkaba* system, and this depends upon the direct rains. The farmers develop a small catchment area on the upper side of the field and rainwater is harvested for farming on the lower side.

In the mountain region of Pakistan, the main sources of drinking water in the districts are wells, springs, rivers, streams, and ponds. Three quarters of the population use these sources.. Only 15 per cent of households have access to piped drinking water.

Karez is a centuries' old system developed by the local people. The system consists of underground waterways linking water from various wells and bringing the water to elevated places. Both *karez* and tubewells are used. Neither tubewells nor *karez* are now able to meet agricultural and domestic needs.

FINANCING FOR IMPLEMENTATION OF WATER HARVESTING SCHEMES

Among the different components of policy on water harvesting, ways of financing the water-harvesting programmes are important. This component is about questions of resource mobilisation for the programme. Should financing be from government sources alone? What should be the share of the government subsidy and what contribution should users make? If it is an economically viable proposition, should there not be provision for credit for users? Should the users contribute a 100 per cent? Who should support technology development and testing? These are important questions in relation to the promotion of water-harvesting schemes. This section attempts to look at the experiences in the HKH (Table 3).

In Bhutan, farmers are obliged to share in the costs of infrastructure and for maintenance.

Table 3. Financing Implementation

Items \ Country	China	India	Pakistan	Bhutan	Nepal
Central Govt.	USD 1.5 billion, USD. 25 billion	Partial investment	Not clear	Only on irrigation and partly on drinking water	Small amount on WH in FINNIDA Project
State/ Provincial Govt.	Research support	Himachal, UP hills, Tamil Nadu	Not clear	This level does not exist	This level does not exist
Local/ Village Council	Support by village council	Not clear	Not clear	Not clear	Contribution by VDC in project area
Household (HH) Contribution	2/3 of the cost	HH contribution	Not clear	HH contribution for channel const.	Rs 300/hh for rainwater harvesting

Agency staff need to be able to carry out better planning, monitoring, and evaluation and to work effectively with user-participatory management. Organization and management costs for irrigation and drinking water have to be borne by the users.

There is a substantial subsidy to facilitate the use of surface water for irrigation in Bhutan. Domestic water supplies were managed through private efforts. It is believed that, as only small quantities of water are required, group efforts are not warranted.

In China, the funds for water harvesting come not only from the government outlay on poverty assistance programmes and allocation of funds for irrigation work, but also large amounts of aid and resources are allocated for water harvesting by the central government.

Since China's open door policy was introduced, the total amount of international loans directly used for the poor in underdeveloped areas is estimated to be US$ 1.5 billion. Most of this loan was spent on water harvesting. The World Bank provided a loan of US$ 0.25 billion for the poor of the southwestern mountain regions of China.

Local government and water users join hands to draw plans for water harvesting. The users themselves provide funds for local construction.

When the project is to address the poverty issue, the local government provides a substantial amount of the funding and local people provide labour to build the structure. Water harvesting can improve the local economy and quality of life, many water-harvesting structures are built by the users themselves.

Both the provincial as well as local governments in mountain regions have encouraged households to build water-harvesting structures for drinking water purposes as well as for farming.

In Quinghai province, the government provides cement and 1,000 *yuan* (8.28 *yuan* is one US dollar) per household as a subsidy; this also includes transport costs. The county provides technical manpower to guide construction work. The users collect local materials, such as sand and stone, and build the cellars by themselves.

In India, the government provides grants to build rainwater tanks. The maintenance is the responsibility of individual households.

A minimum of 10 per cent of the costs is to be contributed by the users in cash/kind/labour. After completion, full responsibility for organization and management is to be taken by the users.

In Nepal, programmes by the Institute for Sustainable Agriculture (INSAN) and Support Activities for the Poor Producers of Nepal (SAPPROS) for small ponds of 25-30 cubic metres in capacity in Gorkha, Lamjung, Chitwan, and Dailekh have been established through strong community user participation and cost-sharing for small-scale irrigation schemes. Plastic lining and tanks and use of sprinklers for high-value vegetable farming by marginal farmers are activities undertaken by these NGOs in Nepal.

The Rural Water Supply and Sanitation Programme funded by FINNIDA has an incentive mechanism. The cost-sharing mechanism of this programme is outlined below.

- Contribution of Rs 300 (68.65 rupees = one US dollar) from each household plus collection and transportation of local materials, provision of unskilled labour, and transportation of construction materials
- Participation of local people in training to demonstrate methods of construction ferro-cement jars
- Provision of plastic sheets, high density polyethene (HDPE) pipes, gate valves, and a sprinkler for each household in small Rural Water for Household Use (RWHU) ponds-

built by NGOs for high-value vegetable farming (unskilled labour is provided by the users)
- Provision of RWHU by the Department of Water Supply and Sanitation at no cost to users apart from organization and management
- Contributions of from 7-15 per cent of costs by users for small-scale irrigation schemes in accordance with the National Irrigation Policy

In Pakistan, there is a substantial subsidy on groundwater mining. No other specific programme for cost sharing is prominent. Further examination of cost-sharing arrangements between the users and the government needs to be undertaken.

IMPLEMENTATION OF WATER HARVESTING SCHEMES

Water-harvesting policies relate to methods of implementation and actors involved in the process (Table 4). It is also important to look into the changing role of the government. What has been the role of the state in relation to the people and people's involvement in such activities? It is also important to understand the implications and importance of legal provisions for water harvesting. It is important to understand the institutional mechanisms necessary to promote water harvesting at different levels. Such mechanisms are in place at users' level, village level, district level, provincial level, and central government level. However, one should not undermine the important role played by communities and households in managing their own affairs. Policy instruments have to create an environment in which households and communities are encouraged to undertake responsibilities to manage their own affairs. People's adoption of water harvesting on a large scale has also proved effective. There are different modes of implementation across the HKH.

Table 4: Methods of Implementation and Responsibilities of Different Actors

Insts. \ Country	China	India	Pakistan	Bhutan	Nepal
Central Govt.	Research/ Policy	CAPART ART	PARC AZRI (Res.)	Department	Department
Provincial/ State	Responsible for implementation	Regulations as in Himachal Pradesh	Support to GW extraction, subsidy	This level does not exist.	This level does not exist.
Local Village	Technical support to HH	Not clear	Not clear	Labour contribution	Local resource contribution
NGO	Not clear	Active	Active in Gilgit Chitral area	Not existing	Active
INGOs	Not clear	Active	In Thar Desert	Not existing	Active
Donor Agency	WB	Active	Not clear	SNV	Active
HH Level	Construction and use	Construction Meghalaya, Mizoram, Tamil Nadu	Yes, in some schemes	HH level for water harvesting	Active

In China, by focussing on water harvesting it is hoped to address the problem of poverty in mountain regions. In order to realise this objective, agencies are actively involved in promoting water-harvesting technologies among the households of mountain regions.

Policy direction for water harvesting is given by the central government as a strategy for addressing poverty by means of making water available for domestic use and for farming.

Research to identify appropriate technologies for water harvesting was carried out in collaboration between the central government and provincial-level government agencies. Once a technology is identified, it is tested at the village level. If a technology is successful, large-scale promotion takes place under the supervision of the local village councils. The users undertake the construction. The users receive partial subsidies and have to contribute to the construction. The structures then belong to the users. Operation and Maintenance of the harvesting structures are also the responsibility of the users.

In India, a high-level committee has been set up in Himachal Pradesh and Uttar Pradesh in the Indian Himalayas to implement and review policy issues related to Participatory Irrigation Management (PIM). These community-based initiatives are likely to be given legal status under the Irrigation Acts of the States.

Water harvesting has assumed importance in India in recent years. With the growing recognition of the increasing scarcity of water and emergence of many community-level efforts, the viability of water harvesting is being recognised.

The Council for Advancement of People's Action and Rural Technology (CAPART) has been supporting individuals and NGOs in rainwater harvesting under the Advancement of Rural Technologies (ARTs). It supports Himalayan villages by supplying them with rainwater tanks.

Under the Accelerated Rural Water Supply Programme (ARWSP), 5,993 rainwater tanks have been installed in individual houses in 198 villages.

Apart from the Central Government effort, the State has about 10,000 rainwater tanks built by different communities at their own expense. In recent years, government agencies and NGOs have become involved in a massive programme to implement community-based water harvesting. At the people's level, a movement for water conservation and harvesting is taking place with positive results.

In Nepal, water-harvesting schemes are being implemented through the Department of Drinking Water and Sanitation of the Government. NGOs and donor agencies have participated in rainwater harvesting schemes also. Implementation is based on a participatory approach. At the people's level, many water-harvesting systems have been constructed. Some of them have proved difficult to maintain .An institutional mechanism for implementation and preservation is very important.

In Pakistan, the *Rod Kohi* system is governed by rules and regulations called *'Kulyat and Riwajat- i-Abpashi* (Rules and Regulations for Irrigation) which were established more than a century ago by the local people. These rules and regulations provide detailed information on distribution of water to different groups of beneficiaries.The Government provides supervision.

Dam construction is supposed to be carried out each year. However, quality of maintenance has deteriorated as a result of negligence and indiscipline on the part of beneficiaries.

Pakistan Agricultural Research Council (PARC) introduced a research programme on water harvesting in collaboration with the International Centre for Agricultural Research in Dry Areas (ICARDA) to generate viable technologies for water harvesting in rainfed areas. The Arid Zone Research Institute (AZRI), Quetta, developed an on-farm water-harvesting technology to increase water storage in cropped areas. Government departments, such as the Pakistan Council of Research in Water Resources (PCRWR) in Cholistan, have invented many techniques to increase runoff and store it in tanks

Terraces with bunds across the slope of the land on a contour in order to cut a long slope into small ones are used for water conservation. Each contour bund acts as a barrier to the flow of water.

IMPACTS AND IMPLICATIONS

Certain implications need to be considered within the framework of a water-harvesting policy. These implications are as follow.

- Inequitable distribution of project benefits among different sections of society within a given geographical area is to be discouraged.
- The weaker the social groups in collective action, more centralized control is required.The stronger the collective action in the community, the greater the power that devolves to the local community for resource management.
- An appropriate institutional mechanism is necessary to implement water-harvesting schemes and their operation and maintenance.
- It is equally important, along with the revival of traditional technology for water harvesting, to re-energize the institutions responsible for conservation and maintenance of the system.
- It is important to make a thorough evaluation of institutional strengths and weaknesses.

Except in China, the monetary benefits of water harvesting have not been highlighted in the review papers.

It is important that the Central Government supports research to identify appropriate water harvesting technologies.

Infrastructural development and urbanisation are complementary activities that have a direct bearing on water supplies. Competition for water between agriculture and other uses has led to shortage supplies. Roads open up access into watersheds, and this, more often than not, is followed by human settlement. Eventually then comes a rise in demand for social services, increasing the pressure on resources. Should there be regulations to maintain the population at a certain figure in mountain areas?

Mechanisms for strengthening local and community-based institutions are important. While infrastructure is essential, it has to be complemented with adequate support mechanisms in the form of functional institutional arrangements.

Shortage of funds and lack of appropriate technologies are serious constraints to water harvesting. Scattered settlements are constraints to drinking water supply programmes, so it is important to identify appropriate water harvesting technologies.

CONCLUSIONS

A definite policy on rainwater harvesting for household and agricultural use can bring about positive changes in the life of poverty-stricken people in mountain regions. Testing appropriate technologies and materials is to be carried out by the central agency. The implementation of these proven technologies should be carried out with the participation of the beneficiaries and local institutions. Local resource mobilisation through users' contributions should be encouraged, so that the users will have a sense of ownership of the infrastructure. The users will then take the responsibility for operation and maintenance.

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Chapter 4

Water Harvesting Practices in Mountain Areas[1]

Mahesh Banskota[*]

Introduction

The availability of clean water, like clean air, has been taken for granted by most communities. However, because of increasing demand, limited supplies, pollution of fresh water bodies, and the soaring costs of providing clean water, the perception of water as a free commodity is beginning to change (Agrawal and Narain 1997). From a bountiful natural resource with unrestricted access, at least for drinking purposes, water is quickly becoming a commodity with a price tag that is bought and sold in the market. Many signals of alarm are being raised about the growing scarcity of fresh water and the urgent need for efficient and equitable water-harvesting systems (Agrawal and Narain 1997; SHERPA 1996).

Broadly defined, local water-harvesting systems include all measures adopted by households and communities to collect water for different purposes. They include tapping various sources, transporting, conveyance and storage, and all the other different socioeconomic and cultural practices that are organized to supply water. Wherever it is in short supply, concerted efforts have been made to ensure its reliable and equitable distribution, at least during critical planting periods. Two different systems have been in operation. One system found in the rural areas of most developing countries is locally operated, small–scale, people-centered, farmer–based or managed, and easy to maintain and rebuild. This system still plays an important role but is now feared to be 'breaking down' and has been referred to as the 'dying wisdom' (Agrawal and Narain 1997). The other systems are those that are driven by modern technologies of large-scale, engineering-dominated, non-participatory, and government controlled or jointly controlled by large firms and governments; and these are playing an increasing role in the supply of fresh water in most urban and some rural communities. In some places one can find a limited degree of interface but this dichotomy has continued to prevail for the most part (Ramaswamy 1998) .

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1 Opinions expressed are solely those of the author

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In most mountain areas, the story of water harvesting is always one of struggle. Indeed, the progress of many mountain communities over the centuries can be perceived from the changing flow of water and the success of their water-harvesting systems. While most mountain areas are relatively well endowed in terms of different water resources, getting it to where and for when it is needed is a serious challenge. The verticality of mountain areas has confined water bodies, generally, either to the extreme heights (in the form of snow or glaciers) or to deep valley bottoms (in the form of rivers and streams), while most settlements are in between and substantial effort is required to transport water from the source to the point of supply. In the HKH mountain areas there is also a marked seasonality in water supplies, particularly in terms of rainfall. There is a short period of high-intensity rainfall followed by a protracted dry season. Unstable geology, slope, and massive discharges make it very difficult and costly to store summer runoff. Thus, when it is available, much of it goes away. It is therefore not surprising that, in most mountain communities, fetching drinking water daily occupies a significant amount of time for various household members – mainly the time of women and children. During the rainy season, getting sufficient water to the fields in time for the limited growing seasons and disposing of extra water are important tasks. In view of all these factors, the struggle for water and the struggle against water have been critical features in survival for mountain communities. Success or failure in these struggles may very well determine whether a community continues to settle in a certain area or abandon it and begin the arduous cycle all over again in another area.

The main purpose of this paper is to provide an overview of the six case studies prepared describing important features of prevailing water-harvesting systems of different mountain communities in parts of India, Nepal, and Pakistan. The paper is organized into several sections – each section discussing common points underlying the different water-harvesting systems (WHS). While there are many similarities to these different WHS, there are also important differences reflecting unique responses to specific environments. The last section looks at community WHS and discusses the critical issues in WHS.

BACKGROUND TO THE CASE STUDY AREAS

There are two case studies each from India, Nepal, and Pakistan. From a water-harvesting perspective, three are from relatively dry areas: Balochistan (in Pakistan) has desert-type conditions and Ladakh (in north India) and Mustang in central north Nepal are both in the rain shadow (Trans-Himalayan) and could be classified as cold deserts (Mushtaq 1999; Khan 1998; Lohani and Banskota 1999). The three other case studies are from relatively wetter areas than the first three– where rainfall is above 1,000 mm per annum. From Pakistan the case study is about a small watershed in Mansehera district in NWFP (Khan 1998). From India it is about a watershed in the Tehri Garhwal district in the State of Uttar Pradesh (CSWCRTI 1998) and from Nepal the case study is from Kabhrepalanchok (Kabhre) district lying directly east of Kathmandu (Lohani and Banskota 1999). In terms of elevation, all three are at lower altitudes (i.e., below 1,500 m). Rainfall decreases from east to west throughout the HKH region and based on this one can conclude that Balochistan (Pakistan) in the west is much drier than Kabhre (Nepal) in the east (Map 1).

In general, all the case studies note that there are fewer difficulties encountered in harvesting drinking water than in harvesting water for other purposes. Drinking water for people and livestock has posed no major problems so far. However, it is a common feature that women spend a lot of time fetching drinking water for the household in all study areas.

There are serious problems in all areas regarding supplies of water for irrigation. The problems differ in nature as well as in severity from case to case. Most water-harvesting systems have focussed on providing sufficient supplies for irrigation, and this is where one can find many complex institutional arrangements for ensuring water supplies in critical planting seasons.

From India, the **Ladakh** case study highlighted the existence of a fairly complex traditional institutional system for irrigation. There are many different systems extant that vary widely from watershed to watershed. Given the limited growing season and the desert-like conditions, the water available is used to maximise the area under irrigation. Because planting periods are short, water has to be distributed quickly to the fields. There is little room for individual decisions, except on one's own land. Water allocation, distribution, and supervision and monitoring are major community concerns. For a few weeks, the entire community is mobilised to manage water distribution. The future of such systems is being questioned, however, not so much because of the failure of the water-harvesting technology, but more on account of the increasing difficulty of mobilising the community members to actively participate in the traditional water-harvesting systems (Lohani and Banskota 1999).

The **Tehri Garhwal** case study identifies many interesting practices of local water harvesting. These include the use of plants for purifying water and the separation of water sources for different social groups. While there has been a significant expansion in the use of modern systems such as lift pumps to supply water, traditional systems are still very important for most people in the watershed in spite of the number of breakdowns and lack of maintenance (CSWCRTI 1998).

Two case study areas in Nepal are similar to those in India. One from the Trans-Himalayan region and the other from the middle hills. In the Trans-Himalayan area in **Mustang**, Nepal (Parajuli and Sharma1999), the institutional mechanisms for water harvesting are complex and well organized and, although similar to those found in Ladakh, there are also many variations. Interestingly, one of the points raised is that the prevailing system has not been modified or redesigned to cater to the increased need for irrigation arising out of the recent introduction of horticulture and tree farming. The priority in the prevailing irrigation system is still for the production of cereals. The second case study area in Nepal is from the middle hills in an area east of Kathmandu in **Kabhre district**. There appears to have been many interventions in the past to improve local water-harvesting systems, both for drinking and irrigation. The most recent example of community mobilisation for water harvesting has been the establishment of a micro-hydro electricity plant for which a fairly elaborate community organization was put into place. Outside resources have played an important role in various interventions. The main issue appears to be the need for greater local resource mobilisation to support present and future water-harvesting activities (Lohani and Banskota 1999).

An important highlight from the **Balochistan** case study area is that increased access to supplies of groundwater has resulted in greater sedentarisation of the community with substantial increases in income for those owning land and having access to groundwater. It is said to have reduced seasonal migration to other areas; changed women's work burden in comparison to the previous nomadic lifestyle; and resulted in an improved quality of life for the community. The main worry at present appears to be the mining of groundwater, its rapidly declining levels, and future supplies. There are important questions about maintaining future water supplies at the current levels (Mushtaq 1999)

The unique feature of the **Mansehra** case study area is the lack of a community organized water distribution system, either informal or formal. Although there is group involvement in various water-harvesting activities, decisions regarding how much water to use, when to use it, and how to use it are made by the person controlling the source. Those living upstream consider it their right to irrigate their fields first. If water is remaining then downstream households can irrigate their fields. Upstream farmers can divert any amount of water to their fields at any time they wish. This practice has evolved into an inequitable and uneven water distribution system. This has forced people downstream to adopt cropping systems that do not require too much water. Some have been even forced to leave their lands fallow (Khan 1998).

OVERVIEW OF WATER-HARVESTING SYSTEMS

Based upon what has been described in the various case studies, it is possible to identify some features common to most water-harvesting systems (Map 1) discussed.

Demand Factors. The demand for water is rapidly increasing. The most common uses are for drinking and irrigation. With many socioeconomic changes, demand is increasing and diversifying. It is a big challenge for local systems that have not altered significantly over decades to to meet this rapidly growing demand for water.

Supply of Water. Various water sources are used by the community for fresh water supplies. The sources discussed in the case studies include rainfall, streams, ponds, springs, marshes, groundwater, snowmelt, oozings, and, in one case, even moisture.

Technology. Technologies for water harvesting vary a great deal from the use of rocks and earth in community-based stream diversion systems to complex lift pumps. However, such technologies appear to be most prominent in three areas of access.

Diversion is the first activity for which some type of technology is used to tap a certain water source and redirect the water to the required location. This is usually to a storage system where some type of storage technology plays an important role. The third area in which technology is used is the distribution and conveyance system through which water is again channelled, stored, and finally used by the household or for irrigation.

In all the technologies used for diversion, storage, and distribution, both traditional and modern inputs, ranging from stone structures to the use of cement, GI pipes, electric pumps, and various types of regulating instrument, are used.

Institutions. Institutions here refer to the organizations and various social practices, rules, and regulations used to harvest water. Water harvesting varies from being a predominantly individual activity to one in which there is a a lot of community involvement. The main areas in which the community plays a role are water allocation between households and fields, the maintenance of water bodies, and conflict resolution between different households over water sharing. Penalties are established and enforced. While most of these are informal, the recent trend is to formalise local institutions involved in water harvesting. With increasing government involvement, the formalisation aspects are becoming stronger. This formalisation is resented to a certain extent by local water-harvesting groups.

Apart from these common features of local water-harvesting systems, more recently government **policies and development projects for** water resources have also been introduced. Policies and development projects influence all the above four aspects. Map 1 shows the policies and development projects circling all the four components of water-harvesting systems. It should also be noted that policies and development interventions do not always support local systems. They may exist in parallel. This is an aspect that requires further study.

There are also other factors such as *environment, productivity, equity*, and *gender* that could have an influence on local water-harvesting systems over time, but these are perceived as indirect impacts on the evolution of the water-harvesting system. For instance, if water distribution is extremely unequal, a time may come when the system either breaks down completely or changes. Inequality may be reflected in increasing poverty/deprivation of some groups and other social conditions that may eventually alter the water-harvesting system. Indirectly, the impact of these factors may be seen over a period of time.

The role of environmental factors is also indirect. Deforestation is reported to have resulted in drying up of springs, forcing households to make changes in their water supply system. Better understanding and proper management of these non-water-related factors and their impacts on water-harvesting systems are very important in terms of long- term sustainability of water harvesting practices.

The Demand for Water

Water is needed for domestic and livestock consumption, for irrigation and milling purposes, and, in some cases, for small-scale power generation. Domestic uses and livestock and irrigation demands are the most important needs in rural areas. Drinking water (both for people and livestock) supplies seem to be adequate in most areas, although there are frequent instances of seasonal scarcity. In most of the areas of the HKH, the current levels of need for human and livestock consumption are less than the level of supply, while for irrigation the demand exceeds supply; and this occurs mainly during the planting season (CSWCRTI 1998; Ladakh Hill Council 1999; Parajuli and Sharma 1998).

There is an indication that the demand for water has increased significantly over the years. In all the studies both human and livestock populations are reported to have increased a great deal, although the rate is somewhat lower in the Trans-Himalayan areas of Ladakh and Mustang (Ladakh Hill Council1999; Parajuli and Sharma 1999). In Garhkot Watershed, it was pointed out that water requirements @ 150 lpd per household was 32,900 litres/day in 1981, and by 1998 this had increased to 53,000 litres/day (CSWCRTI 1998). Increases in demand are also caused by the introduction of new activities such as new water supplies for water mills (Mustang), Micro-hydro Electricity Plants (Kabhrepalanchok), improvements in water supply through piped systems (in all cases), groundwater pumping (Balochistan), and new water lift systems (Garhkot). There are also interesting variations in demand according to altitude and ethnicity. In Garhkot (India) it was mentioned that water needs for livestock are twice those of humans in high altitude zones, nearly one half in middle altitude zones, and almost equal in valley areas (CSWCRTI1998). In Kabhrepalanchok, water demands of Bhramin and Chettri groups are more pronounced than those of the Tamang people, and this is mainly because of the agricultural and livestock practices in the different elevation zones occupied by these groups (Lohani and Banskota 1999).

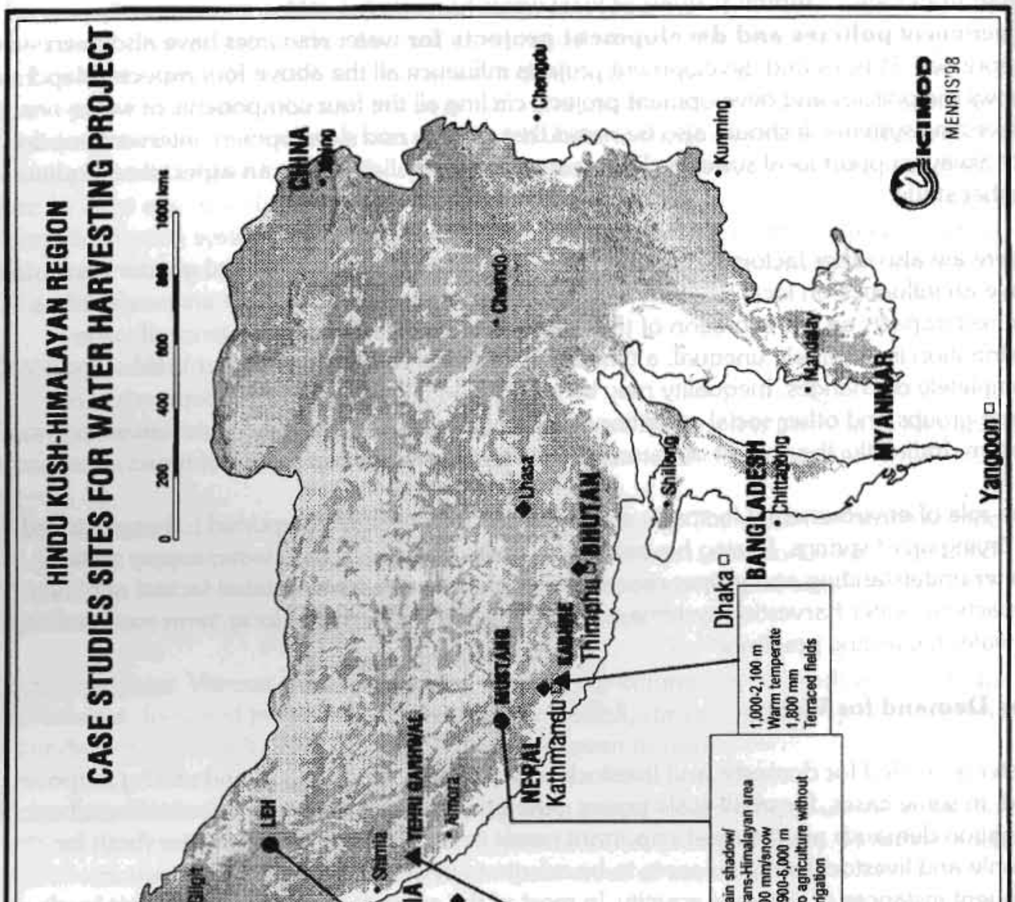

Figure 1: Case Study Sites for Water Harvesting Projects

Some of the main issues regarding water needs are outlined in the following passages.

- There has been a rapid increase in the demand for water for both drinking and irrigation, and it is expected to grow even more in future in all areas. Increases in human and livestock population, intensification of agriculture, and the introduction of new development activities are contributing to this surge in demand for fresh water in mountain areas.
- While there has been no absolute shortage of drinking water reported so far, apart from seasonal scarcity, households are already tapping multiple sources of water to meet the growing demand.
- The demand for water has varied by both elevation and ethnicity. This is a sensitive issue, as it is a potential source of conflict which will need attention in future.
- The case studies do not discuss the changing nature of household water needs by different purposes, and this is an area that needs looking into because efficient demand management will be an important component of future water-harvesting systems.
- All the case studies focus on rural areas. The urban areas present another scenario. Much of the future investment for water harvesting could be influenced by the needs of urban areas, although most water resources originate in rural areas. Equitable sharing of costs for harvesting water resources may be an important issue between rural and urban areas in future.

The Supply Side

Most water-harvesting systems are tapping different sources of local supply. In the areas covered by the case studies there are several sources of water.

Different Sources

Snowmelt is an important source of supply in Ladakh and Mustang and plays a role in Balochistan also. This source is only available during warm periods. It is interesting to note that there is a great deal of variability in water flow, both seasonally and on a daily basis. In Ladakh, the snowmelt of the day is collected and released only in the evening (Parajuli and Sharma1999). Other measures to harvest snow include snow fencing and moisture conservation. Snow fencing is achieved by building walls at right angles to the prevailing winds and this results in deposition of snow on the wall: a form of water conservation.

Rainfall is the next source of supply and is more important in the non-arid lower elevations; for example, the three watersheds of Tehri Garhwal in India, Kabhre in Nepal and Mansehra (NWFP) in Pakistan. The main issue in harvesting rainfall is runoff storage and safe disposal. Most of the time there is either **too little** rainfall or **too much** rainfall, indicating a high degree of variability. In Garhkot watershed, the average rainfall varies from 826 to 2,115 mm, 80 per cent is confined to the three months of the rainy season. The rolling topography and steep slopes result in rapid runoff (CSWCRTI 1998).

Springs were identified as sources of supply in all watersheds. Generally, spring water is stored in tanks and used as and where necessary. These appear to be very important in the watersheds located at lower altitudes. Local words used to describe springs are *dhara* (in Tehri Garhwal) and *mul* (in Kabhre and Garhwal).

Wells were also used in some watersheds. The word *kuwa* appears to be commonly used in Tehri Garhwal, Kabhre, and Mansehra for a well.

Streams and Rivers have been identified as a distinct category in all the case studies. One important point is that the streams and rivers used for local water-harvesting purposes are relatively small ones and not the bigger perennial rivers. The smaller rivers and streams are characterised by large fluctuations in water flow, being almost completely dry in the summer months before the rains. There is, therefore, acute seasonal water scarcity, while inaccessible rivers flow in deep valley bottoms. In the Tehri Garhwal case study it was indicated that the government is providing water from a lift-system by tapping one of these perennially flowing valley bottom rivers. As smaller water sources dry up or flows decrease, more costly and difficult options may become necessary and tapping bigger rivers might become inevitable if stronger conservation and protection of existing water bodies are not implemented along with more efficient harvesting systems.

Underground Water was a very important source for the case study area in Balochistan where lift-pumps are used to pump groundwater from fairly deep wells. There has been a history of using deeper and deeper wells for fresh water as the demand grew and sources closer by decreased. In other areas, wells are also a mechanism for collecting groundwater, but most of the wells were reported to be drying up; and this was the case in particular in Garhkot (India) and Kabhrepalanchok (Nepal).

Other sources of supply also include **'lakes, marshes, and oozings'**— reported only in Ladakh .

Supply Side Issues

Use of Multiple Sources of Water— In the case study areas, all the communities were using most of the available sources of water for different requirements. In some, in spite of all these efforts, there were continuing problems because water supplies were insufficient. Given the likely scenario that demand for water will grow rapidly, supply constraints are going to be a major problem in the future. This raises important questions about new investments, increasing water charges to reflect the additional cost of water storage and supply, better demand management, and greater use-efficiency and reduction of waste.

Supply Bottlenecks — Supply problems have been identified in all cases. In Gharkhot (Tehri Garhwal, India) it was indicated that many water sources in the area had dried up during the past 20-30 years – forcing some villagers to abandon their old settlements and move to new locations (CSWCRTI 1998). In the same area, lack of fresh water from traditional sources has resulted in the government investing in a water-lift scheme for drinking water. In Balochistan, the amount of water available from tubewells is not sufficient and there is a continuing decrease in water tables, ranging from 10-12 ft annually in different areas (Mushtaq 1999). As accessible sources dry up or become inadequate, there will be great pressure for new investments in local water-supply systems.

Control of Water Sources and Access Rights — With increasing demand for water, there is evidence of growing conflict between different groups. First there are already differences in perception between government and local communities about water rights. In the Kabhre Case Study, it was pointed out that The Water Resources' Act 2049 (1992) had established that water is State Property and that, whereas individuals and communities would have usufructory rights for various uses, the State could revoke these users' rights (Lohani and Banskota, 1999). Another source of conflict indicated by the authors is that certain external interventions had destroyed small local schemes operated by the people to carry out large-scale development work, resulting in dislocation of traditional systems (Lohani and Banskota 1999). At district level, the establishment of a separate Water Resources' Committee to adjudicate over water disputes is a new institutional development in the district (Lohani and Banskota 1999).

Similar developments have been indicated by the Indian Case Study from Tehri Garhwal. The State government enacted the Kumaon and Garhwal Water Act of 1975 which terminated the current and customary rights of individuals and village communities. The Act took away the jurisdiction of the local community over all water sources (CSWCRTI 1998). Fortunately, the Act has not made any difference to existing practices so far. If local systems need to be altered for different reasons, it could lead to difficulties in the future.

The other type of conflict is between communities. While most communities are willing to share their water resources with others (mainly those living downstream), there is a limit to this. In Mustang, water disputes have taken place over water for irrigating orchards and plantation trees, both of which have been established through relatively new activities in the area (Parajuli and Sharma 1998). Another dispute reported in the Mustang Case Study was in relation to external support for improving the water conveyance system to one village which resulted in diverting more water than was the custom traditionally. The dispute was registered with the district administration and resulted in suspension of all external support to this project (Parajuli and Sharma 1998).

Watershed Conditions and Depletion of Water Sources — Deterioration in watershed conditions caused by increased deforestation and cultivation and the resulting soil erosion has dried up many springs and wells. With reduced vegetation there is increased runoff and limited groundwater recharge. Open grazing has also been a problem as it has resulted in reduction of vegetation from sloping areas. While some of the case study areas have responded by banning the cutting of trees and introducing improved watershed management activities, in many areas the problems continue. As older systems fail on account of these environmental problems, communities look to governments to provide new water supply systems.

Poor Maintenance — In the past villagers jointly undertook the cleaning and repair of local water-harvesting systems. Those unable to work provided hired labour while people like widows and the handicapped were exempt from contributions. The government played no role in the operation and maintenance of these systems. Many of the systems even had paid watchmen to look after them. Recently traditional systems have begun to break down. As new systems are provided by the government, there is little interest in upkeep of the older ones. In other instances, the effort needed to make the system functional is simply too great for the community.

Water Harvesting Technologies

The technologies for water harvesting are as varied as the communities throughout these mountains. Most communities have provided their own unique touch to technologies that perform functions of water diversion, conveyance, and storage.

Technologies for Diverting and Tapping Water

Technologies for diverting and tapping water range from simple rock and boulder structures to check dams. In most cases, all or a part of the river or stream is blocked and water is diverted to different canals. The flow is regulated by the use of locally fabricated valves for closing and opening. In the case of groundwater, tubewells or lift pumps bring the underground water to the surface. In Balochistan an intricate system of '*karez*' has been developed as underground channels for transporting water for irrigation in a very arid region (Hafez1998).

Storage Technology

Storage technologies include natural and man-made tanks and tank-like structures designed for storing water for some period of time. The release of water from these tanks is generally regulated by the use of simple opening and closing devices. In Ladakh tanks are called *zing*, whereas in Mustang they are known as *ching*. In Tehri Garhwal, water storage tanks are referred to as *naula* and *hauzi* (a tank for animals). As mentioned earlier, *kuwa* refers to shallow wells found in all the warmer watersheds. Use of shallow wells has also been reported in Mansehra district.

It should also be noted that water in the fields is also stored by means of simple structures, especially when fields need to be flooded. There are also storage systems using various types of tanks and pots for collecting and storing water in the house.

Distribution Technologies

In most cases, distribution technologies are based on a series of canals that carry water to the different fields and homes. This is where one finds complex institutional mechanisms that regulate the flow of water along these canals during critical planting periods. The physical aspects are relatively simple, although the use of cement and pipes to make these systems more permanent has increased. However, the amount of water that goes to the field during planting season is a socially-determined process. This process becomes more elaborate with increasing scarcity of water as seen in the arid zones of the Trans-Himalayan areas. In some of the areas (reported in Mansehra) wooden channels are also used to distribute water.

In Situ Water Storage and Harvesting

In all cases one finds many references to technologies used for *in situ* water storage, water distribution, and control of runoff (Khan 1998; Hafez1998;Ladakh Hill Council 1999; Lohani and Banskota 1999; Parajuli and Sharma 1998; SHERPA 1996). These are as follow.

- Level terracing helps to retain rainfall and control runoff. The length of terraces depends upon slope and soil structure.
- Field bunds built of earth or stone to hold water in the fields for a period of time.
- Earthen ponds are used as drinking water sources for livestock.
- Afforestation is important for improving the overall water supply in the watershed.
- Roof-top rainwater harvesting during the rainy season is becoming popular.
- Modern Piped Water Supply Systems

In all the case study areas, some of the population is benefitting from modern piped water supply systems, although their numbers appear to be relatively small. This is seen as the future alternative to local water-harvesting systems.

Some of the main points regarding changes in technology are as follow.

- Traditional technologies are based on local resources and cost little to maintain and manage. However, they are labour intensive, and it is becoming more and more difficult to mobilise adequate labour at the time when and in the place where it is needed. There are many reasons for this labour problem: outmigration of men for jobs outside the area, breakdown in traditional patterns of control over land resources, different individual priorities, and access to alternative water sources are among them.
- Introduction of and expansion in modern technologies are constrained primarily by the lack of resources. Although, as the Nepal case study points out (Lohani and Banskota 1999), the need to mobilise local resources and become financially viable is recognised, this is not seen in practice. There is, at present, great dependency on outside support and subsidies for the use and expansion of modern systems of water harvesting.

Institutional Dimensions

The organizations, both formal and informal, responsible for the management of water-harvesting systems vary significantly, some have over a hundred years of history while others have only recently been introduced. There are examples of individual, community, private, and government systems (Uphoff 1992).

Types of Organizational System

<u>Individual Ownership/Private System</u> —The highlight of this system is that the individual has complete freedom to use the water in any way she/he desires. Obviously, she/ he has to make all the investments needed to operate the water-supply system. This type of system was reported in both the case studies from Pakistan. In the case of Balochistan,installation of deep tubewells for irrigation of one's land is an entirely private decision (Mushtaq 1999). It is less apparent in Mansehra, although even there the person who has the access to water appears to be under no obligation whatsoever to share it with others (Khan 1998). There is some community participation for maintenance, but this appears to be more a case of mobilisation by water-controlling households. There are no apparent water benefits that induce the community to participate.

<u>Informal Working Arrangements at Community Level</u> — Under this arrangement, households do not have a regularly working community organization but have instead agreed to an informal working arrangement which is visible and activated whenever there is a task to be fulfilled. Working rules are well known and accepted by the community. Everyone is willing to abide by them even without a formal organization to oversee them. If and when there is a problem, the community organization is quickly activated and acquires the legitimacy of a formal organization. This type of organizational set-up was reported on in Tehri Garhwal and Kabhre district in Nepal for traditional irrigation systems (CSWCRTI 1998; Lohani and Banskota 1999).

In Tehri Garhwal there is a roster that identifies the water requirements of different households and areas. This has been worked out on the basis of land holdings in the 1940s.

This system is still followed today (CSWCRTI 1998). Within each group, the redistribution of water is another separate issue. In Kabhre also one finds informal committees deciding about water sharing in older irrigation systems, but there are no written rules (Lohani and Banskota 1999).

Control Community and Management — In the case of community control and management there is a formal, local organization with different positions and responsibilities for the management of water resources for irrigation. This is seen in both Ladakh and Mustang where fairly elaborate sets of rules (written in the case of Mustang) have been laid down on almost all aspects of irrigation. Rules deal with with the date of commencement of water harvesting, the selection of different office bearers and their duties and responsibilities, entitlement to shares of water, and the role of different households (Ladakh Hill Council 1999; Parajuli and Sharma 1998). A *gempa* (a small group of people) heads village organizations and provides the overall leadership for all social, agricultural, and development activities such as water management in the village. The *gempa* is also subject to many rules to ensure accountability and proper management (Parajuli and Sharma 1998). In Ladakh, the *Pabchu* system has been described in detail as the process by which a village without access to a water source receives water for a certain period in the critical growing season according to clearly set out rules and norms (Ladakh Hill Council 1999). There are some areas that have no right to any water from streams because they have access to water from alternative sources such as springs and marshes. In order to provide legitimacy to the system, it was well integrated with both religious activities and political power. The overall organization appears to be similar in Mustang. The extensive role of the community organization is to ensure adequate irrigation of all lands in the village during critical planting periods. Election of office bearers and their role in ensuring proper water distribution according to water shares are complex arrangements. In both cases, the systems in place appear to be fairly rigid because of the need to distribute water quickly over a very short planting period. It should be noted that these community organizations are not considered official or legally recognised by the government, as they are not registered with the government as per the set rules and regulations. In Mustang it was reported that, in order to receive local governments funds, some of these local organizations have registered themselves as water user groups (Parajuli and Sharma 1998).

Formal Local Organizations — This is clearly a new trend. Local project activities are using beneficiary organizations and user groups as mechanisms. This kind of organization has been reported in all the case studies, but references are found most in the Kabhre case study. Water projects are undertaken as an offspin by separate organizations established for irrigation and micro-hydro projects (Lohani and Banskota1999). In Tehri also there is a movement to promote water-user societies (CSWCRTI 1998). The Balochistan case study also reported that some development projects had started to work with beneficiary organizations for water harvesting (Mushtaq 1999).

Local Government — Local governments have also been active in improving local water-harvesting systems. However, this appears to be fairly limited. In the Tehri Garhwal case the head of the local government becomes a *de facto* contractor for most government projects at the local level for the area under his jurisdiction (CSWCRTI 1998).

Provincial or State Government — Provincial governments (state/county level) are also involved in bigger water-supply systems over areas under their jurisdiction: examples being groundwater supplies in Balochistan and lift-water supplies in Tehri Garhwal.

Water Allocation System

One of the main responsibilities of the organizations managing local water-harvesting activities is the implementation of an agreed system of water allocation. In the case studies, different systems of water allocation have been described. Allocation takes place primarily when the main crop is being planted.

Water Shares Based on Land Holdings — In many cases, water shares were based on land holdings. The total land holdings were divided into a certain number of water shares. The time needed to irrigate all the land was determined by dividing the number of water shares by the number of days the water was to be allocated on a daily basis. Daily water shares were estimated and water was allocated accordingly. Within each share it was again redistributed according to the convenience for irrigation. Water shares were determined according to land holdings called *thok* in Teri Garhwal (CSWCRTI 1998). Each water share corresponding to a certain amount of land holding, was referred to as *chyure* in Mustang (Parajuli and Sharma 1998) .

Water Allocation According to Tanks — In Ladakh, water was allocated under the *pabchu* system of tanks or *zings* (Khan 1998; Ladakh Hill Council 1999). It was sealed in the evenings and the water was allowed to collect. The next day it was released for irrigation on a turn by turn basis. All the water bodies were closely watched by different households during the critical sowing period so that no rules were breached.

Prior Appropriation — Prior appropriation was also commonly reported, although certain agreements had been in place for a long time and these were observed by the community.

Private Ownership —The most clear-cut case of private ownership was for groundwater harvesting in which lift pumps were used to supply water to the orchards. The water pumped out by the households from their land was considered their property.

User Groups and User Fees — User groups and user fees were new developments reported in Nepal. A new irrigation project had established a user group and had also stipulated the fees to be paid for using the water for irrigation. In a way, the fee reflected the amount of water one was authorised to use and is a growing practice in local irrigation systems (Pushpandagan and Murugan 1998).

Conflicts

Several conflicts are pointed out by the case studies, and these were in relation to (i) water appropriation among riparian parties and (ii) the sharing of costs for development and maintenance. The case studies have pointed out that the conflicts were eventually resolved. In one instance, the conflict was resolved after the government project paid the full cost of the project. In another, the dispute remained unresolved and the project had more or less closed down.

Maintenance

Traditionally, maintenance has remained an important responsibility of the organization responsible for water harvesting. It should be noted that all the case studies indicated major breakdowns in many traditional irrigation channels, tanks, wells, ponds, and diversion structures. This is a new development indicating that local water-harvesting systems and their structures, in spite of their critical importance for daily survival as well as for agriculture, are facing problems. Some of the reasons for this breakdown are environmental, others are socioeconomic and institutional. While there is some progress in terms of introducing new water-harvesting systems through different government programmes, the role of local water-harvesting systems is still very important (Uphoff 1992). Increasing breakdown in local water-harvesting systems has serious and far-reaching implications for local food supplies and agriculture in mountain areas.

Water Policies and Development Interventions

Despite all the positive intentions of most water-related policies, all the case studies stressed that there is no recognition of the customary rights of the community in the use of water. In both the Tehri Garhwal case and the two cases from Nepal, it was mentioned that new water policies had explicitly identified that water was the property of the state. This gives the state the right to revoke user rights whenever necessary (CSWCRTI 1998; Ladakh Hill Council 1998; Lohani and Banskota 1999; Parajuli and Sharma 1998).

Fortunately this has not been implemented to the letter. There are other provisions in the Acts that permit the devolution of water management authority to local water user groups. However, even here the Acts fail to recognise those traditional bodies not formally registered with the authorities, thus creating problems for many traditional groups in the context of access to critically needed resources (CSWCRTI 1998; Ladakh Hill Council 1999).

In the Pakistan case study, water policies relevant to local water harvesting were not identified, apart from groundwater pumping for which there is a law that prohibits the installation of pumps within specific limits. It is pointed out that this law is not followed simply because it is difficult to administer (Mushtaq 1999

There are a number of other problems identified by the Nepal case studies in relation to local contributions and subsidies. The policies stipulate that a certain percentage should be contributed by the local people. This is, however, observed only by government departments. INGOs implementing water projects have provided full subsidies with no local contributions for water projects (Ladakh Hill Council 1999; Lohani and Banskota 1999).

Productivity

As water is a basic human need, supplies of clean drinking water are important for the overall health of the people. Water-borne diseases are the most serious problem in most rural mountain areas in the HKH. Such diseases are responsible not only for poor health but also for the high rates of infant mortality. Adequate measures need to be taken to guarantee safe drinking water.

In the case studies there were several references to the use of polluted water. There was also one case in which a high level of nitrates was found in the water (CSWCRTI 1998).

With regard to the impact of irrigation on agriculture, discussion is limited. Details for on-farm impacts of irrigation are available but not specifically for mountain areas (Chaudhry 1994). First, in three of the case study sites, there can be no agriculture without irrigation because of the arid, desert-like conditions. In Ladakh the irrigation system supports traditional crops with fairly low productivity and needs to be supported by more research. The case study from Kabhre points out that cropping intensity with irrigation can reach 300 per cent, whereas without irrigation it is only 125 per cent (Lohani and Banskota 1999). In the Mansehra case study, one finds that the farms that have water grow rice and wheat whereas those without grow maize (Khan 1998). Although the precise impact on productivity is not discussed, the case studies indicate that reliable and adequate irrigation systems are crucial for agricultural development and reduction of poverty in mountain areas (MOWR/DOI 1996).

Equity Aspects

Information about equity aspects is quite circumstantial. First, as discussed under productivity, there is a substantial difference in cropping intensity between farms with and without water. Second, although upstream farmers have prior appropriation rights, sometimes this is carried too far and downstream farmers are forced to leave their fields fallow (Khan 1998). In Ladakh and Mustang, where water scarcity is greater than in other areas, greater attention appears to be given to equity aspects than in the other systems. In Ladakh, a water official or *churpun* is appointed to ensure that no fields are left unirrigated (Ladakh Hill Council 1999). Similarly, in Mustang the water shares are distributed in such a manner that all have access to some water for irrigation (Parajuli and Sharma1999). In the case study from Tehri Garhwal, equity problems were raised with respect to certain social groups and tail-enders. Because water distribution follows land-ownership pattern, there is an inbuilt inequality in the distribution of water. Development projects may also contribute to the growing inequality by concentrating development activities in lowland areas. This has been reported in the case from Kabhre (Lohani and Banskota1999).

Gender Dimensions

According to the case studies, women are responsible for fetching drinking water for both the household and the livestock (Khan 1998; Ladakh Hill Council 1999; Lohani and Banskota 1999; Parajuli and Sharma 1998). This has been referred to as 'soft' work in one of the case studies (CSWCRTI 1998). Another interesting point raised by the Mustang case study is that women work with the head of the animal (inside the house) while men work with the tail (outside the house) (Parajuli and Sharma 1998). It has been recognised that fetching water is difficult work, and even more so in mountain areas. Further details on gender aspects are missing, although most of the case studies have pointed out that currently there is no decision-making role for women in the management of local water-harvesting systems.

Environmental Aspects

The case studies point to the increasing deterioration of the environment and relate it to the depletion of water resources. In the case from Balochistan, there is a reference to denudation of forests and ranges leading to desertification and abandonment of farmlands (Mushtaq 1999). The Mansehra case study refers to deforestation and a decrease in the supply of spring water (Khan 1998).

Ladakh presents a somewhat different picture of community activities with a strong harmony with nature reinforced by social, cultural, and religious practices. Water sources are not only protected but also revered. Notwithstanding, there are many rapid socioeconomic changes that are undermining some of these strong pro-environmental value systems (Khan 1998).

In Tehri Garhwal, the tradition of protecting springs and treating them with different medicinal herbs is falling out of practice. High levels of nitrate in the water caused by the uncontrolled use of chemical fertilizers are reported (CSWCRTI 1998).

There are strong indications that loss of forests has led to a decrease in water supplies. The communities also seem to understand this quite well, although their responses appear to be limited.

CONCLUSIONS

Common issues emerge from discussion of local water-harvesting systems in the different case study areas. All of these issues may not be equally relevant in all cases, but they nevertheless are valid to some extent. Improvement in local water-harvesting systems can be brought about by either upgrading existing systems or introducing new systems; and this is already the case in many instances. However the pace of expansion of modern, government-supported technologies (such as groundwater lift pumps) for water-harvesting systems is quite slow and represents a relatively small proportion of the total systems in operation: this is the situation in spite of the growing commitments to improve water-harvesting systems in the countries concerned. The implication on resources of replacing traditional community or individual water-harvesting systems with modern ones is important and replacement also seems somewhat unrealistic. The best option is to place equal emphasis on improving existing practices and provide new ones wherever feasible. At a time when water scarcity is compelling societies to change their past notions of water as a free good, failure to take advantage of the vast local resources mobilised by the community to develop water-harvesting systems would be an unfortunate wastage of resources. It is in this context that priorities have been identified.

Strengthen Local Water-harvesting Organizations

Barring a few cases, most local water-harvesting systems are based upon community organizations. These are organizations of the water users themselves, and it is this ownership factor that has sustained these systems in the past (Uphoff 1992). In view of the changes in the socioeconomic conditions, both local and non-local, some older systems are beginning to fall apart. Because of this, there is an increasing tendency to depend less and less on community management and look after one's needs and requirements through new investments in different technologies and other arrangements. As long as water is plentiful, there may be room for individual adjustments but, over time, this will become more difficult as water scarcity increases. With increasing socioeconomic change the need for water will grow very rapidly along with the growth in population. Clearly, unless the local community steps in, there will be no workable solutions. At the same time, the present needs cannot be managed by very loose types of local organization. Organizations have to be capable of handling funds, hiring staff, allocating water efficiently and fairly, enforcing rules and regulations, and becoming involved in many other tasks that take a great deal of effort. In the example from Kabhrepalanchok in Nepal, the efforts made to strengthen local organization for the management of the hydroelectric project is a good example of the type of effort needed. In this project local people are enabled to make decisions about every aspect of project planning, implementation and operation, and fund raising by themselves.

Motivators have been attached to the community and its various groups to work on different aspects. The guiding principles of the project are based on organizing the local beneficiaries, encouraging savings, developing skills, encouraging women's participation, and protecting the environment (Lohani and Banskota 1999). It may not be possible to have the same intensity of focus as the above project when it comes to dealing with many local water-harvesting systems. It is important to emphasise that traditional community-based resources have many positive components, and these need to be adapted and improved to meet the new realities on the ground. If left to themselves, organizations may be unable to cope with the new challenges thrust upon them by outside forces.

The Changing Role of Government

In the past there has been a tendency for the government to operate in parallel to local systems, giving priority to modern, externally supported technology and inadequate attention to the management and financing aspects. While this may be changing to some extent with the increased emphasis on participatory approaches and the need for local co-financing, governments often choose to undertake new activities rather than improving old ones. Clearly, given the rising demand for water, many new projects on water harvesting will be needed, but these should not be undertaken at the cost of existing systems. As a matter of fact, by building on existing systems, one could provide more extensive coverage with strong community support. In order to move in this direction many changes are needed in existing rules, operational practices, and other areas to enable the government and the community to work together. Unless this becomes a deliberate policy, the present dichotomy will continue with the local communities unwilling to participate in activities that have been imposed upon them from outside. In the long run, this will result in a waste of scarce resources, benefitting no one. The specific areas in which changes are needed so that the government and the community can work together to improve local water-harvesting systems will vary from area to area and need to be studied more carefully.

Improving Environmental Management and Preventing Loss and Damage to Renewable Natural Resources

Environmental change has been singled out in many of the case studies as an important reason for the breakdown of local water-harvesting systems. Deforestation is probably the most common reason given for the drying up of streams, springs, and wells. Increasing soil erosion and landslides have also disrupted local water-harvesting systems, and the community has found it very difficult to reinstate them. Natural factors, such as powerful earthquakes that result in landslides and debris flows, disturb water sources. While it will not be possible to cope with some of the bigger natural events, there are many things communities can do and have done in the past to protect and manage water sources and water-harvesting systems. Vegetation cover, land-use management, slope stabilisation measures, and river and stream embankment protection are some of the past practices and need to be emphasised and supported. A critical problem is that most of these activities are labour intensive and local labour is not as easily available or as interested in doing unpaid or community work as in the past. In many areas like the cold deserts, mobilising labour has been quite difficult. Conservation of natural resources and environmental management have to also be taken into consideration as economically rewarding activities so that people start making investments in these areas. This raises important questions about resources for these activities and we need to look at beneficiary issues and pricing mechanisms carefully.

Appropriate Technology

Questions of appropriateness have been raised with respect to both existing and modern technologies for local water harvesting. In traditional systems, the low level of efficiency has been the main problem. Frequent breakdowns, leakages, and inadequacy of control mechanisms were certainly not such big disadvantages in earlier times when the demand for water was low and labour was plentiful. Now, at a time when every drop of water is needed, improvements are essential. With simple interventions, such as plastic pipes to replace open channels, it has been possible to increase water supplies and prevent leakages. At all points in the water-harvesting continuum, it is possible to think of improvements, and these need to be looked at closely. Insofar as modern systems are concerned, the principal problems are costs and management. If local people had to pay for systems that are over-designed and capital intensive; that require sophisticated skills to handle and operate; and, most importantly, lack adequate maintenance back-up, they would be unaffordable. Appropriate technology is a location-specific issue, and it is difficult to generalise in terms of the main areas in which improvements are needed. An hour with the local people can result in identifying many of these problems and gaps. Consultation with the people should not be restricted to identifying the problem. They should also be involved in working out the solutions. Sometimes new developments in different areas may be unknown to local people and here outsiders could have a role in soliciting their assessment about the appropriateness of these technologies. This continues to be an important area in spite of all the work that has been done and which is still in process.

Demand Management

This is probably the most difficult area for the future and will also be one of the most critical issues in the management of water resources. It is not true that rural people do not understand the scarcity value of water. Already, in many areas, people spend long hours every day fetching limited amounts of water. The *pabchu* and *chuyre* systems seen in the Trans-Himalayan areas are beautiful examples of community regulated systems of water distribution.The amount of water one gets for irrigation is based on water shares that have been worked out and which are well accepted. In other areas also there are fairly clear notions of water distribution based upon assessment of needs. All of this applies primarily to the irrigation of the main food crop. With increasing diversion of irrigation for new activities, such as horticulture, tree planting on private lands, and others whose benefits are not community wide, there is reluctance to participate. There is also the problem of industrial and downstream demands for water and, in most instances, these actors have not made any investment in the water harvesting system. As users and demands diversify, the complexity and the conflicts are likely to multiply and a system for demand management by all parties concerned will be needed so that water is not misused.

There are many aspects to demand management. The experience so far in urban areas with measuring and pricing the use of water has not proved to be very successful, as the concept of paying for basic uses of water is still not accepted. At the same time, private supply of water to those that can afford it has been increasing, and the question here is whether or not the price of water reflects its scarcity value. Differentiation of demand by type of need and use of water is not going to be easy and yet, without concerted efforts to do so, the scenario for fresh water supplies and the sustainability of local water-harvesting systems look quite bleak.

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Chapter 5

Social Aspects and Local Water-harvesting Systems:

A Review of the Prevailing Systems in Hindu Kush-Himalayan Communities[1]

Mahesh Banskota

INTRODUCTION

The main objective of this paper is to look at social aspects of different local water-harvesting systems, on the basis of the case studies reviewing some of the prevailing water-harvesting systems in different parts of the Hindu Kush-Himalayas. Social components refer to all social decisions and actions by households in a community about different activities in relation to water harvesting. Social components include individual responsibilities, participation, and rules and regulations that have evolved over time in terms of who gets how much water at what time, penalties for violators, appointment of office bearers, and the issues concerned with transport, distribution, and use of water for household and agricultural purposes. The focus here is household use, although other uses are also taken into consideration. While there are similarities among the cases, there are also important differences as each area has developed its own unique features over the years.

Five different systems and their underlying social systems are discussed,although the information from the case studies is not equally comprehensive. The first one is from Kabhrepalanchok district in Nepal, followed by Tehri Garhwal (India), Ladakh (India), Mustang (Nepal), and Balochistan (Pakistan). While some systems like the *pabhchu* (in Ladakh) are very old, they are not static and, depending on the needs, have changed over time. For instance, even in the *pabchu* system, providing meat as a form of payment to another community for permission to harvest water has been replaced by cash contributions. The rich diversity of social mechanisms involved in local water harvesting emphasises the important role of community participation in the past. Today there are attempts to introduce new forms of community participation in local development activities, but these are undertaken without adequate understanding of existing systems. The next section briefly discusses some of these social dimensions in different areas of the Hindu Kush-Himalayas.

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[1] This chapter is based on the Case Studies from India, Nepal, and Pakistan prepared for the Water Harvesting Project of ICIMOD.

***MUL, KUWA* AND *KULO* (CHA KHOLA WATERSHED IN KABHREPALANCHOK-NEPAL)** [Lohani and Banskota 1999]

Mul, Kuwa, and Kulo are commonly used local terms for describing springs, wells, and irrigation channels respectively. Only a few households are lucky enough to be next to these water bodies. For most households, water has to be carried from a distance—for both drinking and irrigation. It is to transport and share water smoothly that households get together and work out different approaches for supplying sufficient water at the right time and to the right place.

There is a long history of group action for water harvesting in the Cha Khola watershed. Traditionally it has involved the supply of labour and the use of local skills. Little cash was used. Rules for water distribution are agreed upon and a system for regular repair and maintenance is established. Much of this is informal and agreed upon by word of mouth and passed on from one generation to another. More formal management bodies are also being created, although these are reported to be dominated by local elite groups or local politicians. The area in question is predominantly settled by Tamang ethnic groups along with a few other groups such as the Bhramin, Chettri, and Newar. The settlements are, however, ethnically homogenous. There are no major differences in water-harvesting practices among ethnic groups. The social response to water harvesting has varied according to changing needs over the years rather than according to ethnicity. Being relatively well endowed with water resources, it has not been difficult to solicit the collective action needed, as the demands made on households for water harvesting are not very taxing.

Tapping Mul (Springs)

There are different responses to the use of springs. One response has been for individual households to use polythene pipes to bring water from the spring directly to their homes. There is little or no collective action here. All the costs are borne by the individual concerned. In some instances, the individual provides limited amounts of water to other households, at least for drinking. The second response is one in which well to do households provide most of the resources needed to tap water, but the water is used by all the neighbours. Because of the difficulty in getting cash contributions, well to do households provide the cash while others contribute free labour. The third response consists of sharing the costs for water equally among all members of the community. The fourth response consists of mobilising external support from different sources to meet the costs of water supply systems. In such cases, local people may contribute their labour. Whenever there is any type of permanent construction, a formal committee is established and registered with the local authorities. If local households are benefitting from the system, it is the custom for one member from the user households to help with the maintenance and repair of the system. With the growing use of polythene pipes, maintenance now involves cash contributions as well as labour for the replacement of damaged pipes.

Operating Kulo (Irrigation Channels)

There are different types of *Kulo*. Some are micro-systems involving two to five households irrigating about one hectare. Others are larger systems that involve 15-20 households and irrigate about 2—25 hectares. In the area, there is also one externally funded irrigation system involving 400 households and irrigating about 150 ha. This has established a separate management system.

The locally built irrigated systems are operated through an oral code of practices based on collective agreement among user households. Each member of the household participates in the clearing of channels and repair during the rainy season. The code for water sharing is such that upstream farmers first irrigate their fields followed by downstream farmers. As there is sufficient water during the rainy season, few problems have been experienced. In winter there is insufficient water in the channels and it is supplemented with water from other sources and shared in a manner that is generally accepted. There are no formal bodies to supervise the operation of the local system. Cheating is resolved by a stern warning to fellow users. No serious conflicts have been experienced so far.

A new system was recently introduced establishing a larger irrigation system in Chakhola from smaller ones. Users of a number of smaller irrigation schemes built locally agreed to combine and create a bigger system in order to increase the flow of water and reduce maintenance costs. Conflicts arose about the extent of contribution by upstream and downstream farmers. The upstream farmers were not willing to contribute as they claimed they did not need a new system because they already had adequate supplies of water. As downstream farmers needed the new system because of the long distance between the intake and their fields, they were later willing to contribute fully. However, while this discussion was going on, the government agreed to grant funds for the entire project and the users did not have to make any contribution. A user group has been registered and an Executive Committee of Nine Members from the 400 households was elected. Charges were fixed for irrigation at Rs 600/ha for *bari* (uplands) and Rs 1,200/ha for *khet* (lowlands). The entire length of the canal is cleaned twice, once for the rice season and another for the wheat season. Two watchmen have been hired to guard and regulate the distribution of water. So far there have been no major conflicts in the system.

In the last few years, emphasis on working through local user groups has increased. Externally funded projects have also provided motivators to interact with local people to begin the process of formally organizing themselves, establishing women's groups, and keeping a record of decisions and finances. There is more encouragement for formalising informal methods and practices.

Another important change has been the decline in local contributions to projects funded and managed by government organizations. This has eroded local ownership of many water-harvesting projects. More recently NGOs have been attempting to revive some of the earlier group cultures and practices among various communities.

Conflicts about Water

A conflict arose when upstream farmers refused to pay for the new permanent canal. This was resolved however when the government paid in full for the project. Another conflict involved a number of settlements. All the potential users did not participate. The chairman of the local government (Village Development Committee) formed his own committee and took over the contract. Different settlements later complained about the size of pipes used, lack of water in the pipes, and absence of records about use of funds. A more serious crisis is emerging as hotels on top of the hill buy land with springs and pump all the water to the hotels. Differences have arisen between the hotels and the local community regarding the use of springs, pollution of these springs, access to land for laying pipes and encroachment of public lands. None of this has been resolved so far.

One can conclude from the above discussion that, in the above cases, there are two important social aspects. The first deals with conventional systems which are mainly informal and have a strong oral tradition. The mobilisation of the community for maintenance and repair appears to be the most evident social activity with limited regulation of water distribution through hired watchmen. The second social aspect is being developed in new projects in which the emphasis is on local participation through formal mechanisms for all aspects of local decision-making and management. As these systems are recent, their progress needs to be monitored. Because water supply is relatively plentiful (even if it is critical in the summer growing season), social aspects as reflected by different institutional mechanisms are quite informal and not too well defined in terms of individuals roles. In future, however, this could change as need for water increases with increasing size of families, commercialisation of agriculture, changing seasonal demands for water, and increasing competition for water between agricultural and non-agricultural uses. With an increase in demand and limitation in supply, institutional challenges are likely to increase in future, and experiences from new projects with formal structures will provide valuable lessons.

Naula, Hauzi, Dhara and *Guhl* (Tehri Garhwal Uttar Pradesh) [CSWCRTI 1998]

Naula, Hauzi, Dhara, and *Guhl* are local words for wells used by people, ponds for livestock, springs, and irrigation channels respectively in the Garhwali language. Gharkot watershed in Tehri Garhwal of the Indian Himalayas lies between two big rivers, but the area suffers from acute shortage of water, particularly in the upper reaches. The area is mainly inhabited by Rajput and Bhramin groups, but there are also tribal and other caste groups. Settlements are homogeneous in the sense that the Rajput and Bhramin live together, while other tribes and caste groups live separately.

Drinking Water

Water harvesting in dug-out ponds is an old practice. Water-collection tanks to store percolated water,called *naula* (for use by people) and *hauzi* (for use by livestock), have been constructed throughout the watershed by the community. These are revered by the people: religious rituals are observed at the time of their construction and water purification and treatment are carried out with medicinal plants and fruit and large shady trees are planted nearby. Usually water from a *dhara* or spring is directed to the tanks; and today one finds that they are lined with cement. When water is scarce, a roster for water distribution based on family units that stretch back for three generations is still followed. When a drinking water source is situated between two villages, it is shared during different hours by the villages. In one case, one village receives water from 10 p.m. to 3 a.m. while the other receives water for the remaining period. A village watchmen is paid to check that rules are followed. In some areas water is bought at one rupee per litre during the dry season. Each household can buy about 20-25 litres, usually after a long wait. It is mentioned that, as a result of deforestation, road construction, earthquakes, and inadequate maintenance, many of these ponds, tanks, and springs have dried up or are in the process of doing so. One interesting practice in the area is the use of separate drinking water sources for upper castes (Bhramin and Rajput) and lower caste groups. The custom is that the latter are not permitted to even touch the drinking water sources of the upper castes. When it is absolutely necessary to provide water to lower castes from a source used by the higher castes, a higher caste person collects the water and gives it to the lower caste person.

Tap water supplies are handled by the government. At times of scarcity supply is restricted to 40 litres per family at a time. If more becomes available additional amounts are supplied. On special occasions when some families need more water (such as in marriage ceremonies), neighbours share their quota with the family.

Irrigation

Much of the area is rainfed and only small parts of the cultivated areas near perennial water sources have provision for irrigation. All water-harvesting systems are managed by village communities through the *Gram Sabha* (village assembles). Based on population and cultivated land, water requirement rosters have been kept for almost three generations. Surface flow of water is channelled to a *Guhl* (cement-lined tank). Each filled tank irrigates a defined command area. All the land owners of the area prior to 1950, i.e., before the abolition of the landlord system, are members of the informal group for managing the tank irrigation system. All the land owners prior to 1950 are described as *thok* and each land owner is a *thok*. Each *thok* is the unit of irrigation for different tanks. Any subsequent division of land within the *thok* is not considered as an independent unit. The head of the *thok* is a member of the informal irrigation group. Each *thok* is allotted water for 24 hours. Subdivisions within *thok* are managed internally. *Thok* closer to the water receive it first and pass it on to the next one. As far as possible tanks are filled before releasing the water. It is interesting to note that paddy nurseries are raised near water sources even on others' land by mutual consent and without any payment. During the dry season tail-enders do not demand water because they know it is scarce, but they also do not contribute to maintenance of canals and tanks during this period. The villagers jointly undertake the cleaning and repair of the irrigation system by removing silt and other obstructions from the channels and the tanks once before planting paddy (summer) and again before planting wheat (winter). Each household with irrigated land participates. Those unable to help with the work provide hired labour. Widows and the handicapped are exempt. Maintenance and cleaning of channels inside one's own field is the responsibility of each land owner. When major repairs are needed all beneficiaries contribute an equal amount of labour and funds. Sometimes support is also received from the government. Barter within the groups, i.e., *thok*, is also permitted.

In the past the development of irrigation in the hills was left more or less to the cultivators and was not considered the responsibility of the government. After 1947 the State Government, through its Department of Irrigation, modernised some of the traditional systems and also created a few new ones. Most villagers are of the opinion that the Irrigation Department or the government organizations need not interfere in the existing institutional arrangements for irrigation. Yet, the local community has become more dependent on government support for repair and maintenance. Each group prepares an estimation of the repair and maintenance costs and receives support from the village assembly to proritise activities and forward them to the Minor Irrigation Department for support. The Department has its own rules and priorities. The funds for the approved activities are given to the Chief of the Village Assembly to carry out the work. He works like a contractor for government-supported projects.

There have been instances of conflicts over water sharing and use. Most conflicts are resolved on the spot by village elders. In case the village elders cannot resolve the conflict, it goes to the Village *Panchayat* (elected council) which seeks the advice of the elders about resolving the conflict.

Water use norms, upkeep of the system, and other practices are also subject to review over time, depending on the circumstances. Insofar as the role of women is concerned, it has been restricted to looking after the water needs of the household and livestock. When men are absent, women also participate in irrigation-related activities. Although women do not represent the *thok* there are no rules that explicitly prohibit their participation either.

A number of important points can be drawn from this example. First, the drying up of ponds and tanks could be to some extent perceived as a consequence of the breakdown in the underlying institutions. This needs to be examined more carefully. Secondly, as in the earlier case, there are two systems operating concurrently: the older one based on the *thok* and the more recent ones introduced by the government. By linking the tanks with irrigation of the *thok*, a system has been established in which it is in the best the interests of the *thok* to maintain the tanks. It is not clear, however, how many *thok* were facing problems with their tanks and why. This aspect also needs to be studied. Third, the dependence on the government for basic repair and maintenance also emphasises the need for an active local system. Earlier, when resources and labour needed to be mobilised from the community, institutional mechanisms that had local legitimacy were very important. Since government support has replaced local contributions, the role of local institutional mechanisms could also be declining. Government assistance may be playing a role in the deterioration of local water-harvesting systems instead of strengthening them.

THE *PABCHU* SYSTEM (Ladakh Hill Council 1999)

The socio-institutional process underlying water sharing between the villages of Sakti and Chemrey in Chem-rak watershed near Leh (Ladakh, India) is referred to as the *Pabchu* System. The Chem-rak watershed has three independent villages: Sakti, Chemrey, and Kharu. Sakti is located in the upper reaches of the watershed and enjoys a natural advantage because it receives water before the other villages. Chemrey is located further downstream and depends on the water coming through Sakti. Kharu is further downstream and has no claim on the water and depends on locally available springs, oozings from marshes and meadows, and the surplus water released by upstream villages.

Under the *pabchu* system the villagers of the downstream Chemrey village use the water for two nights and the intervening day while the villagers of Sakti, with a larger population and more extensive cultivated area, use it for seven days and six nights. In order to begin the *pabchu,* representatives of Chemrey visit Sakti village with meat and beer on the third day of the third month in the Ladakhi calender. At present, Rs 500 is paid in lieu of the meat. Every time Chemrey wants additional water for irrigation, a bottle of barley beer has to be provided to Sakti.

The actual *pabchu* starts on the eighth day of the fifth month of the Ladakhi calender. On this day, one member from each of the 41 families proceed to the canals to divert the water. The team is led by two water overseers, one from each of the major groups, and there are also two supervisors who oversee the entire operation and fix the seals on the mouths of the canals. Each family is responsible for watching certain canals, and this is detremined by drawing lots and is fixed for a period of three years. The water overseers are also elected by the villagers from among persons who are leaders and have influence. This supervisory position, which was held earlier by members from prominent families, is now determined through nomination.

In the past the monastery also participated in and contributed its own religious personnel for the activity, but this practice has stopped. The family representative, water overseers, and supervisors leave for Sakti in the afternoon following the sounding of the Royal Gong. In the late afternoon the water overseers fix a wooden seal on each of the canals so that water can flow to Chemrey. Meanwhile those assigned to watch at various headwaters of the canal proceed to their respective locations. The water flowing down is stored in tanks. In some of the canals water is retained because, if the canals become completely dry, the fish will perish. At five in the evening once again all diversions are closed and water passed on to the tanks storing water for Chemrey. At about four a.m. (when sparrows start singing) on the third day all those who have been guarding the canals for the past two nights start for home, signalling the end of *pabchu*. Thereafter the non-*pabchu* period begins.

The water collected in the two tanks is again distributed by dividing it into four equal parts. One of the major challenges of the *pabchu* system is the fact that 40 or so people have to spend 36 hours guarding 50 or so canals during each round of *pabchu*. It is already difficult to get all the households to participate. Similarly, repairs are undertaken with funds provided by the local government, rather than by the community that has traditionally maintained the system.

Water supplies are always a very sensitive issue between different communities. Sakti and Chemrey have also had many tense moments in the past. However, over time a system considered relatively equitable by both parties has evolved and is accepted by all concerned. It is now facing problems, and these need to be carefully addressed by the community concerned as well as by the government.

First, the extent to which the *pabchu* system can be used to meet water requirements for the whole year is in doubt. With increasing intensification of agriculture,made possible by introduction of other technologies such as drilling and tubewells, the overall value of the *pabchu* system could be decreasing. It still has an important role to play in the critical period during which it has been used. The limited supply of water is the main problem in a situation of rapidly increasing and diversifying demands, and new options are becoming more important.

Second, the *pabchu* system is a labour-intensive process and very taxing upon all the household representatives who participate. With more men seeking jobs outside, the burden is falling on women. If ways can be found to reduce the labour intensity, these should be explored.

Third, support from the government for all kinds of repairs and maintenance has started to undermine traditional willingness and enthusiasm for participation and provision of inputs by the households. The breakdown has reached the stage at which, unless government support becomes available, there will be little repair or maintenance work. This is a recent phenomenon and indicates how quickly traditional practices can fall apart.

Fourth, the *pabchu* system was reinforced by many cultural and religious practices. It was believed that spirits that protected people lived in the springs and marshes and therefore these needed to be kept free from pollution at all times. People were brought together because they worshipped the same gods, and this was further reflected and reinforced by agricultural and cultural activities. Times are changing with increasing monetisation and commercialisation. People appear less and less willing to be bound by traditional practices if they conflict with pursuit of their new economic activities.

Fifth, the introduction of new technologies for water supply systems is also influential to a certain degree. Tubewells, sprinklers, rainwater harvesting, and use of plastic pipes have been practised by both individuals and communities. As individuals become more independent with investments in their own personal systems, they become less willing to participate in *pabchu* and other practices. If there is a more reliable private water-harvesting technology than the ones they have, individuals increasingly invest in these private systems.

The *pabchu* system is not going to be abandoned immediately and, just as it has experienced changes over the years, it is also likely to change even more in future. In the past, the pace of change was relatively slow, but now it will speed up on account of pressures from many different sides. The problem is not so much the survival of any one system, but more the erosion of mechanisms of self-reliance and increasing dependence on external support and inputs. Established social practices fall apart, and effective alternatives take a long time to develop.

The real challenges are for the new institutions that are a part of the local governance system. How will they intervene in future to allocate and regulate the use of very scarce resources without causing conflict and economic loss? Clearly the focus should be on improving the capacity of local organizations based on the strengths of traditional systems.

***KUHL, KAREZ* AND *SAILABA* FARMING** [Hafez (ed) 1998]

Kuhl are irrigation channels diverted from river/tributaries. These are found frequently in northern areas of Pakistan. *Kuhl* can also be diversions from the collection from a spring. The entire community plays an important role in the construction of the main irrigation channels, as well as in the equitable distribution of water. Depending on the need, wooden and underground channels are used. Considerable inputs are needed for their maintenance, and usually the community works together. The process of irrigating a field begins by flooding the nearest field, followed by the next. In the second irrigation the process is reversed with the last being first.

Participatory management is employed for the distribution of water. Each family is assigned one full day to irrigate its fields. In case there are 20 families, each one's turn will come after 20 days. However, each adjoining family may share water for half a day. On that particular day all family members are busy irrigating their fields. Farmers insert spades in the ground to see if they can be completely inserted. If so, the ground is considered properly irrigated. Another sign of an adequately or well irrigated field is if the soil breaks apart when it is thrown upside down. Complex irrigation schedules have been developed as per the growth of the major crop.

A *Karez* is an irrigation system using underground channels, and it has played an important role in the agricultural development of Balochistan. *Karez* have played an important role in the life of sedentary communities in Balochistan. The role of the government in the past was limited to guaranteeing the land and water rights of the communities along with occasional investments. The government did not interfere with the local water-harvesting system. Water management has been a major community exercise. It has involved the fair and efficient distribution of water, prevention of water theft, and coordination of cleaning and repair work. Special irrigation managers and watchmen are also appointed and are remunerated by the community in different ways. Both of these positions were kept separate from the political leadership in order to ensure that water management was fair and free from political disputes of any kind. Being dependent on the community also made the position accountable to the community. The maintenance of *karez* has become more and more difficult with rapid depletion of groundwater levels. In some areas, *karez* have disappeared almost completely. While there is awareness of this problem and some effort has been made to protect the *karez*, the future for this system is precarious.

The availability of deep tube-wells to pump groundwater has opened the option of high-value horticultural development in many areas. Whenever groundwater can be tapped through pumps, it is being harvested at very rapid rates. There is little regulation of groundwater mining, and in some areas farmers are being forced to put in deeper and deeper tubewells. There is some concern about depletion of groundwater, but little action has been taken to regulate its use. Most of the systems are individual or family based with government providing subsidies for purchasing pumps and electricity.

Sailaba farming is another method of local water harvesting being practised in Balochistan. This is the harvesting of flood water runoff in catchments for crop production. Farmers construct level terraces with embankments to hold water. Terraces are flooded sequentially. The rights of all communities are fully recognised and water is apportioned among them.

The evidence of community involvement in the arid mountain areas of Pakistan is also similar to other areas. The community mechanisms are strong and still exist, but these are beginning to face difficulties. When the *karez* dry up on account of excessive extraction of water by tubewells, the community based system of *karez* management will no longer be feasible and more households will opt for tubewell irrigation, further weakening the *karez* management system. The impact in terms of technology on the breakdown of traditional systems and organizational options is quite apparent in this case.

The *Chyure* System [Parajuli and Sharma 1998]

Ghyakar Khola watershed in upper Mustang in the Trans-Himalayan region of Nepal has some interesting social and institutional features in terms of local water-harvesting systems. Except for irrigation, all other uses of water take place according to the needs of the household. For uses other than irrigation, the supply exceeds demand. As a result, the villagers use water as and when required from their respective systems as long as they remain operational. However, for irrigation, water is allocated to all the villagers based on the water shares they own. Irrigation requires more water than other uses and, during peak periods of irrigation, demand for water exceeds supply. In such a situation, without a principle for allocation agreed upon by the villagers, competition to use scarce water increases and ultimately leads to disputes over water.

Water allocation for irrigation differs according to the crops grown. Cereal crops are irrigated with water allocated according to villagers' water shares, locally known as *chyure*. However, orchards and trees have no defined basis for allocating water as these are new plantations. Villagers irrigate orchards and trees with water not needed for cereal crops.

Water rights for irrigation purposes are attached to the land. Transfer of land rights automatically transfers the water rights of that land. Local inheritance laws prevent the fragmentation of land and water rights. Usually, the eldest son inherits the land. Consequently, the water rights attached to the land are automatically transferred to the eldest son.

The feeder canal conveys water from the source to the irrigation tank from which the flow of water is regulated. Every evening when the tank becomes practically empty, the outlet of the tank is closed and the water from the feeder canal is stored through the night. The stored water is released for irrigation through the outlet the following morning until the tank becomes practically empty. This cycle is repeated daily.

In Ghyakhar village, water is distributed to villagers on a turn by turn basis in a one-week cycle. Distributing water in a one-week cycle makes it easy for the villagers to remember their turn for irrigation. For example, if a villager first receives water on Monday, he continues to receive water on the same day throughout the irrigation period.

In Ghyakhar Village, the water available for irrigation in the gravity canal system is considered to consist of 22 shares. To prepare a rotational cycle for one week, the first 21 shares are divided into seven shares. The remaining twenty-second share is then merged with one of the seven by means of a lottery. In the second cycle of irrigation, this last share is merged with another group for equitable distribution of water. Thus, in each cycle of irrigation, six groups consist of three shares, while the seventh group consists of four shares. The groups are prepared so that land holdings are near one another. By doing so the transport loss during water distribution is minimised. Also, there is a rule that one villager cannot have more than one share in a group irrespective of the total number of shares he/she owns. For example, if a person has four shares he/she will be located in four groups, with a maximum of one share in each group. Thus, each group consists of at least three or more villagers. After forming the groups, the lottery method is used to decide the ordering of irrigation for each of them.

Each group receives water for one day. Usually the irrigation time starts at about five in the morning and ends in the evening when the tank becomes empty. Depending on the cropping season, the *gempa* (executive body of village representatives) decides the duration for each group. It is the responsibility of the *gempa* to close and open the tank at the time specified.

Although the time-sharing rotation is a popular method of distributing water equitably, in Ghyakhar this method is not practised. The reason it is not practised is that time-sharing by rotation is suitable only for uniform flow. In Ghyakhar, since water is released from an irrigation tank, outflow is not uniform. There is more water in the morning and it decreases gradually throughout the day. This means that villagers have had to adopt 'irrigation in turns'. Water from one villager's terrace is diverted to another villager's terrace after the former finishes irrigating his/her terrace. However, the number of terraces each farmer is authorized to irrigate in turn depends on the water shares owned in that group.

In this village, equity among the groups is determined on the basis of time-sharing. For example, each group receives water for one day. However, within a group, equity is neither determined with respect to the flow nor with respect to the time water is received, but rather on the basis of the number of terraces each villager irrigates in his/her turn, and this depends on the water share he or she owns. For example, if a villager with 0.5 units of water shares is allowed to irrigate one terrace in his or her turn, another villager with a one-unit water share is allowed to irrigate two terraces, one after another. This measure of equity has advantages over the time-sharing measure of equity because it accommodates soil types, terrace conditions, and conveyance losses.

The *gempa* members are responsible for operation of the system. In case of problems the *gempa* members depute a person to inspect it.

System maintenance involves repairing the intake, cleaning the canals, and desilting the irrigation tank. Wherever closed polythene pipes are used, either in gravity canals or in piped canal systems, pipes choke occasionally, requiring maintenance. From experience (by hammering the pipe on its top surface), the villagers can trace the points in a pipeline that are choked. The maintenance activity in this case involves cutting and rejoining the pipes after removing the debris.

To maintain a gravity canal system, resources are mobilised according to a villager's water shares. However, to maintain the modern, piped canal system and water mills, households contribute equally, although the actual use of water (benefit from the systems) may not be the same for all households. For example, a household with a large number of family members may use more drinking water than a smaller houshold. The main reason for this system is that it keeps administrative costs low.

The irrigation tanks are desilted once a year, usually after the monsoon season. Maintenance immediately after winter requires mobilisation of more resources than at other times, especially labour. With the use of polythene pipes in the canals, maintenance requirements have decreased. In each maintenance period, the *gempa* members decide upon the day for maintenance and labour is mobilised according to need. The amount of labour mobilised is always in proportion to the number of water shares in a gravity canal system. For example, in Ghyakhar, depending upon the volume of work 44, 22, or 11 labourers are mobilised. When a total of 44 labourers are to be mobilised, a villager with a one-unit water share provides two labourers. Note that the total number of water shares in Ghyakhar is considered to be 22 *chyure*.

Unlike the gravity canal systems, there is no fixed timing for the maintenance of piped canal systems and water mills. They are maintained as and when needed and their maintenance requirements are quite low. The fact that many of the canals have been aligned through the village has reduced the amount of time it takes the women to fetch water for the household and indicates some gender sensitivity in the water-harvesting system.

In Ghyakhar no water-related disputes have been reported. However, in nearby Chaile Village, it was learned that sometimes minor disputes occur over the distribution of water for irrigation of orchards and on-farm trees, as there there are no defined water distribution rules for irrigation of these new cropping activities. Interviews with the villagers in Chaile indicated that, with increasing demands for water, villagers are thinking of enforcing rules for new crops. The *gempa* members still resolve water-related disputes.

Being relatively isolated, these villages in Trans-Himalayan areas of Nepal have faced little pressure from outside, indicating that they have quite strong traditional irrigation management systems. New materials, such as plastic pipes and cement, have been introduced. The rapid escalation in demand for water seen in other areas is also not apparent here to the same extent. Agricultural intensification and diversification have also been somewhat slow, although there are indications that some modification is needed for off-season irrigation of orchards and tree farms. The types of change seen in other areas, such as commercialisation of the local economy and the undermining of traditional sociocultural and religious systems, is also limited at present, but could become stronger in the future. The relationships of local organizations with the government and other development bodies in the area are changing as the need for improving technologies and various types of support increases. Changes become inevitable for the future, and it will be important to monitor these.

CONCLUSIONS

The foregoing discussion of social aspects, particularly institutional arrangements behind local water harvesting, provides only a few examples from a vast range of alternatives that vary from watershed to watershed, from one farming system to another, and from one community to another. When water needs are limited and supplies are relatively plentiful, there is little regulation, except perhaps in exceptional circumstances. However, when demand exceeds supply in critical planting periods, the community must step in to regulate the distribution of water supplies in a manner that is most suitable for the community.

Notions of acceptability are not always the same. In rainshadow areas, where the growing season is limited and all the available agricultural land must be irrigated, the emphasis is on providing water as quickly as possible to all land owners. In many cases the system is quite rigid and strictly enforced for the irrigation of all land. The ownership issues apparently take a secondary role. Intricate arrangements ensuring that water reaches the targetted areas are made; this is a system supported by all aspects of local life. Today some of these are falling apart for many different reasons. Irrigating all the land possible does not mean extending it unrealistically. After a point downstream, villages have no water supplies. In other cases, water appropriation rights are based on control of water sources and there is no consideration of other users.

Contributions from participating households are agreed upon in terms of maintenance. The concept of water shares goes quite far back, in some instances as far back as one hundred years. What is very clear is that with increasing scarcity of water during critical planting periods, the guidelines for water use will become more specific and the enforcement stricter.

Traditional systems, as indicated from the discussions so far, have a number of very important advantages. First there is participation by all households, contributing to a strong sense of ownership and responsibility for the systems. To a great extent this has been possible because of the similarity of activities in sociocultural, religious, and economic life. Most of the people practised subsistence agriculture and when there was no water there was no food. The sense of belonging to the community and identifying with all its priorities and problems was also reinforced by collective participation in cultural and religious events.

The next important aspect was that conflicts were resolved on the spot, and this was accepted by the people. Changes were slow, but the systems were not static. Another factor was that the systems were relatively simple and could be operated and maintained by local households. In some instances, special persons were appointed, but in most cases the local households participated in and rebuilt the system every time it broke down.
There are, however, a number of important problems also.

- Irrigation management has concentrated only on the main crop grown in a specific period, and water use at other times is unregulated. As some households will increase cropping intensity and diversify crops, their demand for water will rise, creating conflicts over the off-season use of water as well as about the maintenance of water systems. This aspect needs to be studied in future.

- The traditional systems are labour intensive to a large degree and, with changing socioeconomic conditions and with household members either outmigrating or taking up work outside the agricultural sector, it is becoming difficult for households to provide the required labour inputs. This is probably the biggest problem. The alternative is to use hired labour, and this increases the cost of repair and maintenance. In some areas finding hired labour may be a problem.
- The entire water allocation system is based on the prevailing system of land distribution. When the land distribution is unequal, water access is also unequal, and, as households become more aware of this as a result of ongoing sociopolitical changes, there will be less willingness to participate in traditional systems and increasing interest in finding private solutions to water problems or in moving towards more equitable participatory systems.
- Households have the option of using individualised systems when they have access to new technologies. This reduces the willingness of households to participate in and contribute to collective systems. Tubewells, pumps, and electricity have facilitated the development of individual systems in many areas.

Insofar as the future of the social systems behind local water harvesting in mountain areas is concerned, it is essential to examine to what extent they can be improved in order to cope with the different incoming challenges. One crucial task is to retain the advantages of community participation and at the same time incorporate the new skills needed to make these more efficient and equitable in managing available water resources. The allocation of water between crops, between seasons, between sectors, and between households is likely to become a very complex issue in the future; an issue requiring a difficult balancing act between equity and efficiency considerations. As agricultural modernisation results in the adoption of new crops and practices, water requirements are likely to change drastically and the existing system should be able to cope with this without creating too many conflicts. The roles of external support and organizations are going to be very important in this transition. In the past, all the systems were completely self contained. However, with new requirements new inputs are needed to make these efficient and self-reliant in future. This is an area in which external support can play an important role.

Refereces

CSWCRTI, 1998. 'Case Study on Local Water Harvesting Technologies and Management Systems in Garkhot Watershed of Tehri Garhwal,UP Hills (India) (1998)'. Prepared for ICIMOD's Water Harvesting Project by the Central Soil and Water Conservation Research and Training Institute (CSWCRTI), Dehradun.

Hafez, S. (ed), 1998. *Appropriate Farm Technologies for Cold and Dry Zones of the Hindu Kush-Himalayas*, p153. Kathmandu: International Centre for Integrated Mountain Development.

Ladakh Hill Council, 1999. 'Case Study on Local Water Harvesting Technologies and Management System in a Micro-Watershed in Ladakh (India) 1999' Prepared for the Water Harvesting Project of ICIMOD by the Ladakh Hill Council, Leh.

Lohani, J. and Banskota, K., 1999. 'Local Water Harvesting Technology and Management System Case Study of Cha Khola Micro Watershed in Kabhrepalanchok District'. Prepared for the International Centre for Integrated Mountain Development (ICIMOD) by the Centre for Resource and Environmental Studies (CREST).

Parajuli U. and Sharma, C., 1998. 'Study of Local Water Harvesting Systems in a Micro-Watershed in the Upper Mustang Region of Nepal'. Report Prepared for the Water Harvesting Project of ICIMOD, Kathmandu.

Annex I

Detailed Workshop Programme Schedule

Day One: Sunday, 14 March 1999	
09:00	Arrival and Registration
09:30	INAUGURAL SESSION
	• Background on Workshop: Suresh R. Chalise • Opening Remarks: Director General, ICIMOD • Remarks: Ujjwal Pradhan, Ford Foundation • Vote of Thanks, Saleem A. Sial
10:00	Tea Break and Group Photo
10:45	SESSION – I
	• **Case Studies on Water Harvesting Technologies and Management Systems**
	• Overview of Case Studies: Mahesh Banskota • Highlights of Case Studies • U.P Hills, India: Ram Babu • Ladakh, India: Deldan B. Dana ❖ Midhills, Nepal: Jyoti Prashad Lohani ❖ Mustang, Nepal: Chiranjivi Sharma ❖ NWFP, Pakistan: Muhammad Jamal • Balochistan, Pakistan: Mushtaq Ahmad • Discussions on Case Studies
13:00	Lunch Break
14:00	SESSION - II
	• **Country Reviews on Policies, Programmes and Institutions**
	• Overview of Policies: Prachanda Pradhan • Highlights of Countries Reviews on Policies • Bhutan: Kaylzang Tshering • China: Liu Changming • India: V.S. Saravanan • Nepal: Shanker K. Malla Pakistan: Shahid M. Zia
15:30	Tea Break
16:00	Discussions on Policy Reviews
17:00	End of Day 1
19:00	Reception Dinner Hosted by the Director General of ICIMOD

Day Two: Monday, 15 March 1999

	SESSION- III
09:00	Rural Water Supply and Sanitation Project, Lumbini Zone, Auli Keinanen
09:20	Rainwater Harvesting and Utilization in the Hills of Lumbini Zone, Ramesh Bohra
09:45	Comments by the Community Representatives from Rural Water Supply Project Lumbini Zone, Mr. Lok Bahadur Gywali and Mrs. Kamla Gywali
10:15	Water and Watershed Management in the Indian Himalayas, Chandi Prashad Bhat
11:00	Traditional Irrigation Management in Jumla, Western Nepal, D.D. Devkota
11:30	Tea Break
	Field Visit
12:00-1600	Departure for field to observe traditional water-harvesting systems at Bhaktapur

Day Three: Tuesday, 16 March 1999

	SESSION – IV
9:00	**Group Discussions**
	Group A, Institutional Aspects
	• Policies on Water Harvesting for Irrigation • Policies on Water Harvesting for Household Uses • Equity among Upstream/Downstream Water Users • Participation by Water Users (Both Men and Women) • Local Governance • National Project Working Groups • Management Systems • Networking
	Group B, Financing Programmes
	• Subsidies/Incentives by Governments, Banks, Private Enterprises • Funding from NGOs and INGOs • National Programmes on Water Harvesting.
	Group C, Technologies and Research for Sustainable Development of Local Water-harvesting Systems
	• Traditional Technologies and Their Limitations (*Zings, Spouts, Karez,* Tanks). • Innovations (Ferro-cement Cisterns, 1-2-1 project China, Underground Cemented Tanks, High Efficiency Conveyance and End Use Systems) • Integrated Programmes Including, Water Storage Facilities, Orchards/Vegetables Gardening and Raising Dairy Animals, Tourism.
10:30	Tea Break
11:00	Group Discussions Continued
12:30	Presentation of Groups Recommendations
13:00	Lunch Break
14:30-1600	**SESSION – V (PLENARY)**
	Finalisation of Recommendations

Annex II
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Annex III
Annotated Bibliography

Annotated Bibliography on Water Harvesting in the HKH

Compiled by
Saleem A. Sial
and
S.R. Chalise

Agarwal, A.; Narain S. (eds) (1997). *Dying Wisdom: Rise, Fall and Potential of India's Traditional Water Harvesting Systems*. 404pp. New Delhi: Centre for Science and Environment.

The book deals with the history of water harvesting in the Indian subcontinent— how it developed and prevailed in ancient India and then declined gradually. Examples of the revival of water-harvesting practices are given with an assessment of their potential for success in terms of increased agricultural production and drinking water supplies in areas where water is scarce.

KEYWORDS: water harvesting systems / environment / India

Agnihotri, Y.; Samra, J.S.;Mittal, S.P. (1996). *Boosting Hill Resource Economy through Watershed Management in Hoshiarpur*, Shiwaliks, India. Indian-Journal of Soil Conservation, 24: 3, pp 248-252.

One million hectares of the Indian Punjab, mainly in Hoshiarpur in the Shiwaliks, suffers from problems of soil erosion and land degradation. Consequently, the agricultural economy in the region is low key. A watershed management programme (WMP) was undertaken in a typical hilly watershed of 627 ha in Hoshiarpur, Shiwalliks, in Relmajra village in 1991 to demonstrate how soil erosion from the hills and flood problems in the plains can be minimised, while at the same time boosting the hill economy through the development of hill resources with community participation. Rainwater harvesting, storage, and recycling were an integral part of the WMP. Innovations were introduced on to private as well as community lands. The WMP also gave impetus to a dairy development programme, and an 84 per cent increase in milk yield occurred. A water users' society was formed, and it played a pivotal role in boosting the hill resource economy. A benefit/cost ratio of 1.27 gives an indication of the economic viability of such programmes.

KEYWORDS: watershed management/ India/ water harvesting/ dairy development

Altaf, Z. (n.d). 'Water Harvesting for Mountain Households in the Hindu Kush-Himalayas.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 142-147. (Unpublished).

This paper raises issues of water supplies and future policies about them in Pakistan, a country moving from water surplus to water deficit. A brief description of existing water-harvesting practices is given, e.g., managing spring water, streams, and canals/water channels placed on high ground so that water can be delivered by gravity flow dugwells, ponds, Persian wells, snowmelt, canals, and *karez*.

Policy issues related to competition between upland and lowland communities and between urban and rural users are reviewed. Other issues related to more productive use of water, for crop diversification for example, are discussed. It is suggested that NGOs and water users' associations should play a leading role in the local management of water resources by using integrated and participatory approaches.

KEYWORDS: water harvesting/ policies/ water resources management/ Pakistan

Aslam, M.; Ikram, M. Z. (1994). 'Water Harvesting and Dugwells for Sustainable Water Use'. In *Progressive Farming*, 14 (5) 66-69.

This article gives climatic data of six districts of Pakistan based on either annual or seasonal catchment/cropped area ratios. Water-harvesting for plot boundary plantation and water storage and recharge through mini and small dams are also described. Dugwells are recommended as an inexpensive means of using recharged groundwater for domestic or agricultural uses.

KEYWORDS: water resources and management / Pakistan / water storage / irrigation / water conservation / runoff irrigation / dugwells

Bureau of Water Conservancy and Electricity of Deyang City (n.d.). 'Development of Micro Water Conservancy Works in Deyang City.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 21-24. (Unpublished).

This article narrates a success story about introducing micro water-harvesting works in Deyang city; a place that used to suffer from drought every nine out of 10 years. Micro water-conservancy works composed of micro water-harvesting ponds or cisterns, micro- pumping, and sprinkler irrigation were established.

In 17 villages of Zhongjiang county, crop production increased by 3.2 million kg worth 5.79 million *yuan* (8.28 *yuan* = 1 US dollar) in 1994 and 1995. The cisterns saved farmers 208, 413 working days worth 1.67 million *yuan*, and the fish produced from these ponds totalled more than 0.3 million kg, worth more than one million *yuan*. Water shortages were a key factor limiting economic growth, and micro-conservation works were considered the only way to solve the water shortage problems in the area. Construction of headquarters for micro-conservation of water were established in the cities, counties, and villages for planning purposes. Deputy governors were in charge of these. Engineers and technicians from the bureau helped farmers to plan, design, construct, and operate micro-conservation works.

The works were subsidised by the government through various means, but the farmers have the right to use, transfer, and sell these works.

Cai Kejian (1998). 'Research on the Rainwater Utilisation in Tongshan County.' In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 167-173. September 8-12, 1998, Xuzhou, Jiangsu Province, China. (Unpublished).

As a result of the construction of diversion and storage structures, flood water has been controlled and transferred properly. People have been freed of floods and drought and have changed their town into a region of rivers and lakes where rice and wheat are harvested and fish and fruit have high yields. Rice yields of 15,000 kg per ha have been realised.

KEYWORDS: flood control/ drought control/ agricultural development/ China

Chalise, S.R. (n.d.). 'Water Harvesting for Mountain Households in the Hindu Kush-Himalayas: Issues and Prospects for a Regional Participatory Programme.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 12-18. (Unpublished).

This paper gives a brief review of past and present water-harvesting practices in the Hindu Kush-Himalayan Region and highlights how water harvesting can help to provide better opportunities and also help to improve the ecology of the region, thus contributing towards sustainable development in the HKH.

Water harvesting is appropriate for scattered mountain settlements as rainwater can be harvested extensively by individual households independently of each other and with minimum conflicts over ownership being raised.

Moreover harvesting of rain in the uplands can reduce or retard erosion processes and sedimentation, and this can contribute to flood control downstream. In the HKH, erosion, mass wasting, landslides, debris flows, floods, and sedimentation are major problems, so the benefit of early collection of rainwater in the mountains is evident.

A water-harvesting system designed to match the requirements and preferences of individual households can help a great deal to increase agricultural production and productivity at household level. Increased supplies of water for irrigation can help individual households make better use of their land, provide options of high-value and marketable crops, and open up opportunities for double and multiple cropping. This will provide incentives to individual mountain farmers to select crops according to their marketability and cash value, thus resulting in economic gains.

It is recommended that technologies for harvesting water should be simple and affordable, so that local people can adopt them easily.

Providing water for domestic use by harvesting rainwater or other water sources will be the first step towards reducing the drudgery faced by women and children in the HKH who are burdened with the responsibility of fetching all the water needed for domestic consumption.

KEYWORDS: water harvesting/ Hindu Kush-Himalayas/ water scarcity

Chandio, B.A. (n.d). 'Water Harvesting for Mountainous Regions of Balochistan.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 136-141. (Unpublished).

This paper provides us with an overview of the geography, climate, physiography, and hydro-meteorology of Balochistan, the largest province in Pakistan. There are no perennial or fresh-water lakes in the province and water harvesting is needed. Water conservation by building contour terraces and dykes across the slope and diversion of floods to ponds and construction of delay action dams for groundwater recharge are common. Involvement of water users' groups for participatory management is emphasised as a means of popularising water harvesting. Some of the policies suggested to encourage water harvesting and conservation of threatened water resources include:- i) dissemination of technological information about water harvesting and conservation to end users. ii) introduction of extensive watershed management practices to prevent erosion and augment infiltration, and iii) creation of public awareness through the media and by holding of seminars and workshops about water resource conservation and replenishment methods.

KEYWORDS: water scarcity/ ponds/ delay action dams/ Balochistan

Chandra, S., Singh, R.D., and Dube, S.D. (1996). 'Water Harvesting and Uses of Economically Effective Systems Like Hydram, Sprinklers and Drip Irrigation'. *Seminar on Water Management in the Himalayan Region of India*, pp112-119—Nainital, August 22-23, 1996, Lucknow, India: Society for Himalayan Environmental Rehabilitation and People's Action.

This article discusses the results of economic analyses of sprinkler and drip irrigation systems for water harvested and stored in LDPE-lined water tanks in the UP hills, India. Spring and rainwater are the two principal sources in the area.

Six to eight times less water is needed in drip irrigation systems for tomato and cauliflower cultivation compared to surface irrigation for the same crops. Twenty-five to 50 per cent less fertilizer is needed for fertigation through micro tubes rather than check-basin irrigation. The net profits after deducting the full cost of the drip system and the interest were 132 per cent more for tomato and 156 per cent more for capsicum crops for the first year. On steep slopes water harvested in small trenches or pits of one metre in diameter and 0.75 m deep with the dug out soil placed on the lower half of the pit was found quite helpful for conserving soil moisture and facilitating the growth and yield of fodder trees.

KEYWORDS: water harvesting / water management / sprinkler and drip irrigation / India / horticulture

Changming Liu (1998). 'Rain Water Utilisation as Sustainable Development in China's Water Resources'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 1-9). September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper refutes the claim that rainwater harvesting reduces the flow of rivers substantially. Firstly, a little rainfall can not generate sufficient runoff to supply water to the river; secondly the rainfall collected usually accounts for a very small proportion of the rainfall, e.g., construction of 100 square metre-waterproof surface for each family would make about 25 square kilometres for 250,000 families, and this is only between two to five per cent of a medium- sized river basin (e.g. 500-1,000 sq.km.). On the other hand it can provide water for 1.25 million people. Thirdly, from a rainstorm, the amount of rainwater collected is a minor proportion of the whole runoff. In fact, it may cut down the flood peak, and this is good for soil and water conservation.

KEYWORDS: water harvesting/ sustainable development/runoff/ China

Changxing, J., (n.d.). 'Farmland Rainwater Collection Techniques in China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 38-43. (Unpublished).

Several techniques of water harvesting for increased crop production are presented in the paper. They include terraces, water storage tanks, fish-scale pits, contour hedgerows, and plastic membranes.

Crop yields were 111.6 per cent higher than the yield on a sloping field. Bio-hedges of *Vitex negundo* decreased runoff by 70 per cent and silt production over 90 per cent. In two years, slope gradient decreased by up to six per cent. Land cultivation with furrow ridges increased rain use by 38.5 per cent -82 per cent and wheat production increased by 20 per cent was recorded compared to conventional sowing.

Keywords: water harvesting techniques/ runoff control/ crop production/ China

Danish Hydraulic Institute and Water Branch of United Nations Environment Programme, (1998). *Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Asian Countries*. IETC Technical Publication Series Issue 8. Osaka: International Environmental Technology Centre.

This book gives an audit of different technologies used to augment freshwater supplies in various Asian countries, i.e., Bangladesh, India, Nepal, and Thailand. Some practices and materials to control evaporation losses and technologies to improve irrigation efficiencies of precious freshwater sources are given. Some practical methods to upgrade water quality using desalination, sand filtration and biological pretreatment of raw water are also discussed. Also given are some case studies from Nepal, Thailand, and different states of India. At the end a list of additional references is provided along with table of conversion factors for metric and U.S. Customary Units.

Department of Water Conservancy, Ninngxia Province (n.d.) 'A Guide to Underground Cistern - Water Saving Irrigation Techniques.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 30-33. (Unpublished).

This paper gives a summary of guidelines for the construction of underground water cisterns in Ningxia province, China. Guidelines include instructions for site selection and determination of catchment area, water entrance system, and construction and maintenance of underground cisterns with features such as seepage control. Different types of underground cistern are also described. Ningxia is a drought-prone area, each period of drought lasting from two to six years. Collection and storage of rainwater runoff have proven quite helpful in the agricultural development of the region.

The recommended size for a sediment trapping pool is two to three metres long, one to two metres wide, and one-metre deep. A metal screen is also recommended on the inflow side of the sediment trapping pool. The mouth of the cistern should be 0.3-0.5metres higher than the adjacent ground surface. It should have a cover and water-drawing facilities.

For proper maintenance, the water paths should be cleaned up before rainfall, the entry to the cistern may be closed as soon as it is full of water. Check and repair the cistern to ensure it is in good condition before the start of the rainy season. Cisterns and sediment trapping pools should be cleaned frequently.

Keywords: underground cisterns/ irrigation/ construction and maintenance/ China

Federal Water Management Cell (1996). *On Farm Water Management Field Manual*, Vol. 10. 'Water Harvesting and Spate Irrigation', pp 140. Islamabad: Federal Water Management Cell, Ministry of Food, Agriculture & Livestock, Government of Pakistan.

This manual was prepared for the use of field staff from on-farm water management departments of the four provinces of Pakistan. It contains step- wise procedures for site

selection, social organization, area appraisal, topographic surveys, land-use plan preparation, action plan, and work plan procedures for implementation of water-harvesting projects. Procedures for the design and construction of water-harvesting structures, such as fields, spillways, water ways, diversion ditches, gully erosion control, ponds, and dams, are given.

Guidelines for extension and education for rainfed agriculture, horticulture, social forestry, animal husbandry, and pasture management in watershed areas are also given.

KEYWORDS: water management / Pakistan / water harvesting / spate irrigation / watershed management / social organization

Fu Lianjiang (1998). 'Construction of Comprehensive Dry Farming Technology System to Increase Natural Precipitation Use Efficiency.' In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 185-188. September 8-12, 1998 Xuzhou, Jiangsu Province, China.

This paper discusses techniques to preserve soil water for increasing production. Measures to counteract drought included decreasing ground surface evaporation and surface runoff to conserve water through building terraces, improving soil quality to increase water holding capacity, covering soil with mulch and plastic film, improving water production efficiency, and developing rain catchment and other irrigation works to increase water supplies.

KEYWORDS: drought management/ water conservation/ irrigation works/ China

Fuxue, W; Junlan, H; and Yufeng, W. (n.d.). 'Planning and Design of Rainwater Harvesting Works.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas,* pp 59-71. (Unpublished).

This paper describes planning considerations, design formulae, and material for rainwater harvesting works used domestically and for irrigation. Tiled rooves and concrete in on the courtyard floor are good for harvesting water for domestic purposes. A sediment trapping pool should be built before the runoff entrance of a cistern. Cisterns should be built as close as possible to runoff collecting catchments to reduce runoff loss. The cistern should be built far away from toilets, five metres from cliffs, and four metres from the trees.

While planning an underground cistern for irrigation, any available bituminous road can be used as a runoff collection surface by using existing diversion ditches on the roadside as runoff collection ditches. Runoff from watershed and spring flows can also be diverted into underground cisterns. If there are many cisterns in one place, the distance between cisterns should be more than four metres. Cisterns should be built in stable locations to avoid slope failure/landslides. Wherever possible the bottom of a cistern should be four to five metres above the level of land to be irrigated so that the water stored can be irrigated by gravity.

KEYWORDS: rainwater harvesting works/ planning design and materials

Gupta, K.K.; Deelstra, J; Sharma, KD; Baumgartner, M.F. (1997). 'Estimation of Water Harvesting Potential for a Semi-arid Area Using GIS and Remote Sensing'. In Schultz, G.A. and Johnson, A.I. *Remote Sensing and Geographic Information Systems for Design and Operation of Water Resources Systems*. Proceedings of an International Symposium pp 53-62 (5th Scientific Assembly of the IAHS), Rabat, Morocco, 23 April to 3 May. Wallingford, U.K: IAHS Press.

A water-harvesting strategy is proposed for the semi-arid area of Rajasthan, India, using geographic information systems (GIS). Information on topography and soils was digitised to form the GIS database with land-cover information derived from remote-sensing satellite data (IRS-1A) in the form of a normalised differentiation vegetation index (NDVI). Six basins were delineated using a digital elevation model (DEM) and the total acreage in different slope classes estimated. These maps were used as input to derive a modified Soil Conservation Service (SCS) runoff curve number model that was then applied to estimate the runoff depth of individual storms and summed to derive the annual runoff potential for each basin. Subsequently, basins for rainwater harvesting were prioritised based on the runoff generation potential, the availability of agricultural land, the suitability for constructing water-harvesting structures, and so on. The results demonstrate the capability of GIS and their applications for planning for water harvesting over large areas of semi-arid terrain.

KEYWORDS: GIS and water harvesting/runoff estimation/ India

Heitz, L.F. and Khosrowpanah, S. (1998). 'The Performance of Rooftop Rainwater Catchment Systems on a Small Pacific Atoll Island during The El Nino Drought of 1997-98: A Case Study'. In *Proceedings of The International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 223-230. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper describes the strategies recommended to improve the existing rooftop rainwater catchment system for combatting drought on the Atoll Island of the Federal States of Micronesia. This island depends on rooftop rainwater systems to meet 80-90 per cent of its freshwater uses and suffered from a long drought of more than six months during 1997-98. Some of the recommendations made are 1) during periods of drought RWCS water should be used only for drinking, cooking, and washing dishes and 2) all guttering systems should be able to catch at least 60 to 70 per cent of the available roof surface with minimum leakage.

KEYWORDS: roof top water harvesting/ drought management

Huang Zhanbin. (1998). 'Model of Rainwater-Harvesting Agriculture in Loess Plateau of China'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 339-344. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper presents a strategy for overcoming water shortages and for efficient use of harvested water for agriculture on the Loess plateau of China. The Loess plateau area covers 0.62 million square kilometres and annual average rainfall on the plateau is 443 mm. Thus, the total volume of rainwater is 257.7 billion cubic metres which is 9.2 times the total water consumption from surface and groundwater resources. So rainwater has a good potential for supplying sufficient water to the area. Construction of water cellars of different shapes with storage capacities of from 15-60 cubic metres is common practice for domestic and agricultural uses.

For efficient use water is supplied at critical stages in the crop production cycle using efficient methods of irrigation, e.g., point irrigation, irrigation in a hole lined by plastic film, ditch irrigation, drip irrigation, and permeating irrigation. Hand pumps are used to irrigate an area of 0.27 ha by drip irrigation.

KEYWORDS: Loess plateau/ rainwater harvesting/ water cellars/ China

Ikram, M. Z.; Aslam, M. (1994). 'Land Development for Rainwater Conservation'. In *Progressive Farming,* 14 (5) :60-65.

The article describes the design and use of rainwater conservation practices with benefits of each and principles of land development and land forming in rainfed areas for cropping, plantation, and pasture. The practices explained include the broad channel terrace, ridge terrace, and bench terrace types for crops; eyebrow terraces, conservation catchment terraces, reverse sloped terraces, and orchard terraces for plantation; and other types for pastures.

KEYWORDS: water resources and management / Pakistan / water storage / irrigation / water conservation

Khan, Sardar Riaz (n.d.). 'Water Harvesting and Runoff Farming in Barani (Rainfed) Tracts'. Islamabad: Pakistan Agricultural Research Council. (Unpublished)

This report estimates that 15 million acre feet of runoff water is lost in Balochistan province from rainfed (cultivated, range, and forest lands) areas every year estimated at a 25 per cent loss in runoff. Various *in situ* and catchment-based water-harvesting practices and a plan of action for high, medium, and low rainfall areas have been suggested.

The techniques presented for *in situ* water harvesting are i) contour furrowing, ii) contour benches, iii) broad bed, iv) furrow system, and v) runoff recycling whereas those presented for catchment-based water-harvesting systems are the i) runoff-run on system, ii) desert strip farming iii) road catchments, iv) micro-catchment farming, and v) rooftop runoff collection for household use.

KEYWORDS: rainfed agriculture / water harvesting / soil and water conservation

Kumar, A. and Pant, G.B. (1996). 'Water Harvesting and Recycling to Enhance the Productivity of Rainfed Hill Agriculture in Garwal, U.P., India'. In *Seminar on Water Management in the Himalayan Region of India*, pp133-138— Nainital, August 22-23, 1996. Lucknow: Society for Himalayan Environmental Rehabilitation and People's Action.

This article recommends use of 0.25 LDPE to line ponds for harvesting water from rooftops, surface runoff, and springs. Drip irrigation systems were found to be the most efficient (90-95%). About 40-70 per cent less water was needed and crop yields increased by up to 200 per cent. Growing off-season vegetables such as peas, potatoes, cabbages, capsicum, and ginger and garlic was suggested as a means of increasing farm incomes.

KEYWORDS: water harvesting / water management / India / storage ponds / drip irrigation / springs/ runoff.

Langxin, C. (n.d.). 'Water Storage Tanks for Agricultural Development in Chuxiong, Yunnan, China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 25-29. (Unpublished).

This paper describes the use of water storage tanks for social and economic development in the mountain region of Chuxiong city through 'Five Small' projects using small dams, small water pipes, small ditches, small water storage tanks, and small underground cisterns for water storage. Crop productivity increased by 4,750 kg/ha for maize. By 1995, 154,575 water storage tanks were built in Shuju community, and 85 per cent of the cultivated land was irrigated. The income from tobacco production also increased. The water storage tanks helped to improve the living standards of farmers. Some households had very high maize yields of 15,000 kg/ha.

KEYWORDS: water storage tanks/ irrigation/ China

Li Zuodong (1998). 'Benefit and Vast Prospects of Rain Water Utilisation in Yuzhong County'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 174-179. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

Yuzhong county lies in the western mountainous area of the Loess Plateau. It is notorious for its poverty and aridity. The average annual rainfall is only 380 mm. Ninety per cent of the rainfall is absorbed by thick surface loess and the runoff coefficient is only 0.05 to 0.1. Out of a population of 400,000, two thirds of the people and livestock had problems with water supplies. In dry years, people had to fetch water from places up to 10 km away. To solve this problem, each house was asked to provide at least 100 square metres of paved catchment to collect 20 cubic metres of rainwater per year in a small cistern fitted with a hand pump at a chosen site. This is supplemented by one or two old style original cisterns for irrigation. So the basic model consists of a catchment area, collector- sediment tank, concrete water cistern, water filtering device, and a drip irrigation system.

KEYWORDS: water scarcity/ poverty alleviation/ rainwater utilisation/ China

Liu, C., and Mou, H. (n.d). 'Water Problems and the Significance of Rainwater Utilisation in China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 1-8. (Unpublished).

This paper examines the extent of water scarcity, water pollution, environmental problems, and the occurrence of floods in China. There is a shortage of water to varying degrees in 414 cities in China. For irrigation, there is a shortfall in water supplies of 77 billion cubic metres. An area of seven million hectares suffers from floods every year and 20 million hectares are affected by drought. One third of industrial waste water and 90 per cent of domestic waste water drain untreated into the rivers and lakes, polluting the water substantially.

The paper recommends harvesting rainwater to meet the shortfall in water supplies for municipal and agricultural uses and refutes the notion that collecting rainwater would reduce the flow in the lower reaches of rivers considerably.

KEYWORDS: water scarcity/ pollution/ environment/ floods/ China

Luo Yunqi and Song Guanchuan (1998). 'Precipitation, Distribution and Rainwater Utilisation in Xuzhou City'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation* pp 159-166. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

The paper suggests a scientific computer-based method for effective rainwater utilisation based on the data for annual precipitation, water requirements of crops, and the pattern of high and low water distribution for Xuzhou city. It is recommended that various water storage and diversion structures be built to solve the problem of water shortages in the mountainous region. Building pools, dams, and reservoirs and digging ditches to intercept rainfall are effective approaches to the water shortage problem. Stored water can not provide sufficient water for flood irrigation. Thus, water-saving irrigation methods such as spray irrigation, micro sprinklers, and drip irrigation are necessary.

KEYWORDS: rainwater utilisation/ computer modelling/ èfficient irrigation systems/ China

Mingbo, L. (n.d). 'Micro Water Conservancy Works for the Household[sic] Scattered in the Remote Mountainous and Hilly Areas of Sichuan Province, China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 47-50. (Unpublished).

This paper describes the use of micro water-harvesting works that were instrumental in solving the problems of collecting sufficient water for irrigation and domestic and livestock needs in Sichuan. The paper also describes a strategy for disseminating these techniques, e.g., organization of leaders of the administration and relevant departments; government subsidies and uniform standards of design and construction; examination of water conservation works; and use of funds from different sources. Many examples from different villages in Liangshan Autonomous Prefecture are reported to have carried out many water-harvesting measures; as a result the area irrigated and yields and incomes have increased for farmers.

The major benefits/attractions quoted are low construction costs and return of costs in just one year after completion, easy construction in any place, clear ownership for the households, clear management responsibilities for the owner household, and reduction of soil erosion and floods.

KEYWORDS: water harvesting/ organization/ subsidy/ design standard/ China

Mukerjee, R. K. (1984). 'Water Harvesting Structures: The Need and Design Considerations'. In *Regional Training Course on Watershed Resources' Management and Environmental Monitoring in Tropical Ecosystem* 17 Jan-13 Feb 1984, Roorkee, pp316-325. Roorkee: University of Roorkee, Department of Hydrology.

This article emphasises the importance of precipitation for agriculture. It describes variations in rainfall in India, zoning according to precipitation, economics of water-storage structures, and factors to be considered in designing and maintaining water-harvesting structures. Guidelines for the conveyance of harvested water to the fields and its management and equitable distribution are given.

KEYWORDS: water conservation / water conservation / water storage / water utilisation

Mushtaq Ahmad Gill (1998). 'Crop Productivity Enhancement through Rainwater Harvesting in Pakistan'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 456-468. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper describes a rainwater harvesting project implemented in Pakistan from 1995-96. The author gives details of implementation strategies that emphasise users' participation. The project was mainly for agricultural purposes. It includes results from pilot rainwater harvesting sites. It is stated that soil erosion has been controlled, runoff has been negligible from treated fields, and crop production has increased to 70 per cent. Some training and demonstration centres have also been established in the project areas.

KEYWORDS: rainwater harvesting/ land development/ training and demonstration/ Pakistan

Pacey, A.; Cullis, A. (1986). *Rainwater Harvesting: The Collection of Rainfall and Runoff in Rural Areas*, pp 216. Southampton Row, London: Intermediate Technology Publications.

This book provides a perspective of rainwater harvesting practices throughout the world but particularly from South East Asia, the Middle East, Africa, China and South Asia. Various techniques have been described briefly with design procedures, scope for extension, limitations, and environmental and economic acceptability. Policy issues having implications in terms of food shortages and negligence of rainwater harvesting are also discussed. The book deals with domestic supplies, watering livestock, gardening, flood and erosion control, and agricultural uses of harvested rainwater.

Given the many examples of the advantageous uses of rainwater, there are still numerous villages in Asia, Africa, and Latin America that are desperately short of water and where no efforts appear to be made to collect rainwater and use it.

The need for local organizations to replicate rainwater harvesting techniques is emphasised. The different water-related environmental problems found in India are described: drought and erosion on farms in the central region, waterlogging and salinity in the north, and deforestation everywhere. Rainwater conservation could solve many of these problems, but there are many political and bureaucratic obstacles.

It is also suggested that rainwater collection at home could increase the productivity of households and help improve the health of women and children by saving the time and energy spent carrying water from a distance.

Flood control, erosion control, groundwater recharge, and a reduction in siltation in major reservoirs are possible benefits from rainwater harvesting. Thus rainwater schemes that require public expenditure for conservation measures can be justified on these grounds.

The book also has a bibliography of water-harvesting documents and publications, case studies of socioeconomic analyses, practical manuals for construction of water-harvesting structures and related training procedures, and booklets giving practical details of a single technique.

KEYWORDS: rainwater harvesting / social organization / water supply / erosion / water management

Pandey, S.C.; Singh, R.D.; Dube, S.D. (1996). 'Soil and Water Conservation for Optimum Crop Production in Hill Area'. In *Seminar on Water Management in the Himalayan Region of India*, pp139-152—Nainital, August 22-23, 1996. Lucknow, India. Society for Himalayan Environmental Rehabilitation and People's Action.

The article summarises techniques of soil and water conservation in the N-W Himalayan region of India. It also discusses the limitations to water management, soil, climate, plants, local genetic materials, and groundwater. Three sources for water harvesting and recycling are given - low discharge spring water, collection of runoff from a mini watershed, and collection of runoff generated by impermeable surfaces.

In situ water harvesting and its conservation through bench terracing, contour bunding, graded bunding, contour cultivation, strip cropping, straw mulching, deep tillage, use of farmyard manure, and toposequencing of the cropping system are also described briefly.

KEYWORDS: soil and water conservation / India / water management

Pradhan, P. (n.d). 'Community Based Water Harvesting and Management in the Mountain Regions of Nepal.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 118-129. (Unpublished).

This paper gives a brief overview of Nepal's water resources and government policies on the use of water for drinking, irrigation, hydropower, and industry. A detailed description of the management of mountain irrigation systems by farmers through local communities is also given Potential conflicts between different users and over different uses of water are also discussed.

Development of an irrigation system is usually the first priority of the villagers whenever resources are available. It is estimated that 70 per cent of the irrigation systems in Nepal are managed by the farmers themselves. The cost of developing an irrigation system can be recouped in a few years through increased agricultural production.

KEYWORDS: water harvesting/ irrigation/ community-based management/ Nepal

Pradhan, U. (n.d.). 'Water Harvesting in the Hindu Kush-Himalayan Region: Issues and Prospects'. In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 9-11. (Unpublished).

This paper highlights the role of small water-harvesting structures for the marginalised people living in remote mountain areas. The paper deals mainly with three issues for water harvesting in the HKH

i) The substantive aspects of water harvesting focussing on issues related to management and governance of water harvesting structures, sustainability and state, locality interaction
ii) The needs and priorities of individual countries and the region as whole, particularly with regard to the effects of water harvesting.
iii) The role of ICIMOD

Pradhan, U. (n.d). 'Water Harvesting in the Hindu Kush Himalayan Region: Issues and Prospects.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 9-17. (Unpublished).

In this paper, the authors highlight issues and strategies in the promotion of water harvesting to supply mountain households in remote areas. A water- harvesting system managed and built by individuals and communities supplied water to remote area households. Proper governance and management of these water systems are essential for the development of remote economies.

Equity was considered an important issue in water-harvesting projects. Case studies were recommended as a way of understanding i) existing knowledge on the subject. ii) policy-implementation interaction for infrastructural development, and iii) effects on poverty alleviation.

The exchange and interaction of comparative knowledge and exposure to innovative ideas elsewhere at regional level were considered useful for developing individual country-level programmes. It was said that ICIMOD could facilitate the introduction of water-harvesting programmes by communities, institutions, and governments in the region in order to address the concerns of marginalised groups in mountain areas.

KEYWORDS: water harvesting/ governance and management/

Qureshi, Z. A.; Willardson, L. S. (1995). 'Increasing Soil Moisture and Crop Production by Efficient Water Harvesting Technique'. In: Ashraf, M. M.; Anwar, M. (eds) *Proceedings of the Regional Workshop on Sustainable Agriculture in Dry and Cold Mountain Areas*, pp 161-169. Islamabad: Pakistan Agricultural Research Council and ICIMOD.

This article presents the results obtained from a research experiment conducted in upland Balochistan using catchment to cropped area ratios of 1:1 and 2:1 with an annual rainfall of from 200 to 300mm. The catchment area was ploughed and compacted using a wooden plank to form a two to five mm surface crust for inducing runoff.

The moisture stored in the treated plot was six to 27 per cent higher in catchment to cropped area ratios of 1:1 and 13 to 67 per cent higher in catchments to cropped area ratios of 2:1 than on untreated plots during a three-year experimental period. Grain yields were also three to four times higher on the treated plots than on the control when analysed according to cropped area only.

KEYWORDS: soil cultivation / Pakistan / water management / wheat / agricultural development

Rees, D.G.T.; Ashram, S.A.; Trust, K. (1996). 'Drinking Water and Sanitation for Village Level Implementation: Infiltration Well Technology for the Handpumps in the Himalayas'. New Delhi: Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Areas and Employment, Government of India.

This is the progress report of a programme on rooftop water harvesting in above ground tanks and infiltration tanks for collecting shallow groundwater with hand pumps using local technologies and through people's participation.

The report suggests that water need not be dealt with as a single programme, but should include the other needs of local people such as sanitation, agriculture, income generation, horticulture, soil and water conservation, social forestry, habitat, and cooking and heating. It suggests that such programmes should be supported by programmes on health and hygiene, small savings, child care, and primary health and cultural programmes to involve the local population.

To facilitate the changes required it is also recommended that the people who actually live on the land be enabled to plan, manage, implement, and maintain programmes that relate directly to their daily lives.

The pressure of livestock on the land is another issue raised. The numbers of unproductive animals have to be reduced to the minimum and the animals that remain should compensate for the labour and carrying capacity of the land needed to support them by their productivity.

KEYWORDS: drinking water / sanitation / rural development / water harvesting/ participation/ integrated development/ India

Rural Water Conservancy Bureau, (n.d.). 'Low Cost Water Conservancy Projects in Rural Areas of China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas,* pp51-54. (Unpublished).

The paper gives a review of water-harvesting work completed in China. In total 2.5 million water conservancy works were completed by the end of 1995, including 120,000 diversion works, 330,000 wells, 280,000 public water-collecting reservoirs, 1,450,000 household water-harvesting cisterns, and 320,000 other projects with an investment of 12 billion *yuan*.

The following considerations were recommendations during selection of engineering works for water conservancy projects: reliable water resources, water requirements, natural conditions for construction, project funding sources, labour resources, and maintenance of works. A 'three in one' programme, focussing on water supplies, environmental sanitation, and health education, has been introduced in China.

KEYWORDS: water harvesting/ project funding/ maintenance of works/ China

Samra, J.S. (n.d.). 'Water Harvesting for Mountain Households in Indian Himalayas.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas,* pp 80-89. (Unpublished).

This paper gives a brief account of water harvesting in the Indian Himalayas. The importance of rainwater management to ease the stress of dry periods, flood moderation, and off-site environmental externalities is emphasised. A water-harvesting project completed by people's participation by contributing labour and local construction materials to build bench terraces, cemented tanks, polyethene tanks, and cemented channels, amounting to 50 per cent of the total cost is described. Other water-harvesting practices prevailing in the Indian Himalayas, for example, *in situ* retention of precipitation, bamboo drip irrigation, diversion of streams, use of springs, baseflow harvesting through dugout-cum- embankment type storage structures, hydraulic rams, and roof-top water harvesting, are also described. Successful introduction of new local-level organizations, called water users' societies, for sustainable development, use, and management of water is also discussed.

KEYWORDS: water harvesting/ floods/ mountain irrigation/ people's participation/ Indian Himalayas

Samra, J.S.; Sharda, V.N.; Sikka, A.K. (1996). *Water Harvesting and Recycling: Indian Experiences*, pp 248. Dehra Dun: Central Soil and Water Conservation Research and Training Institute.

This book reviews water-harvesting practices of the past and present in the Indian subcontinent. The designs of different water-harvesting structures, e.g,. dugout ponds, spillways, small dams, and percolation tanks, are explained. Detailed accounts of water-harvesting practices in different regions of India are also given. Other considerations for sustainable water harvesting, i.e., socioeconomic surveys, case studies from different regions of India, and procedures for economic cost-benefit analyses of different water-harvesting structures are described and examples from the field given taking the multiple uses of these structures into account. Many of these water-harvesting structures are economically feasible.

Methods of facilitating people's participation, institutionalisation, and implications of policy issues are also discussed. In conclusion recommendations are given for filling the gaps in practice and policy in future.

KEYWORDS: water resources and management / India / water treatment / water utilisation / water management / watershed management

Shafiq, M.; Ikram, M. Z.; Nasir, A. (1995). 'Water Harvesting Techniques for Sustainable Agriculture in Dry and Cold Mountain Areas'. In: Ashraf, M. M.; Anwar, M. (eds) *Proceedings of the Regional Workshop on Sustainable Agriculture in Dry and Cold Mountain Areas.* Islamabad: Pakistan Agricultural Research Council and ICIMOD.

This article highlights issues responsible for decreasing agricultural production and recommends water-harvesting practices to increase water supplies for crop, tree, and pasture productivity in mountain areas. The water-harvesting practices described include collecting water in catchment basins, ephemeral stream diversion, sloping agricultural land technology, bench terraces, ridging, eyebrow terraces, contour trenches, reverse sloped terraces, orchard terraces, and *in situ* water harvesting.

KEYWORDS: water resources and management / water management / mountain areas / irrigation / mountain farming

Shah, S.L. (1996). 'Identification and Management of Spring Sanctuaries in Khulgad Micro Watershed - Concepts, Methodology and Learning Lesson'. In *Seminar on Water Management in the Himalayan Region of India*, pp55-69— Nainital, August 22-23, 1996. Lucknow, India: Society for Himalayan Environmental Rehabilitation and People's Action.

This article describes results of a study on management of springs and spring sanctuaries to meet household and small-scale irrigation needs in micro-watersheds in the U.P. Hills. Water supplies, for both for drinking and irrigation, were given the highest priority by the people of the area.

Small organizations of beneficiaries using spring water were formed to conserve spring sanctuaries in civil forests, on grazing lands, and on wastelands. Small water-harvesting schemes using RCC tanks, ferro-cement tanks, infiltration wells, hand pumps, and lift pumps are discussed. Tank capacity was determined by calculating the volume of water discharged from the spring during a 12-hour period. Vegetable production, nursery raising, and poly house technologies are recommended for the area.

KEYWORDS: water management / springs / watershed management

Singh, R. (1984). 'Water Harvesting Techniques'. In *Department of Regional Training Course on Watershed Resources Management and Environmental Monitoring in Tropical Ecosystem*, 17 Jan-13 Feb 1984, Roorkee, pp 294-315. Roorkee: University of Roorkee. Department of Hydrology

This article describes methods of runoff inducement such as land alteration, chemical treatment, and soil cover. Water-harvesting practices for runoff agriculture are also given, e.g., runoff farming, water spreading, micro-catchment farming, and desert strip farming. Methods of reducing evaporation from water surfaces and for reducing transpiration from plants are discussed and the advantages and limitations of each method given.

KEYWORDS: water conservation / water conservation / water storage / water utilisation

Suleman, S.; Wood, M.K.; Shah, B.H.; Murray, L. (1995). "Rainwater Harvesting for Increasing Livestock Forage on Arid Rangelands of Pakistan'. In *Journal of Range Management*, 1995, 48:6, pp 523-527. Watershed Management, Department of Animal and Range Sciences, New Mexico. New Mexico, USA: State University, Las Cruces.

Forage production and cover consisting of several plant species, the growth of which was brought about by using water-harvesting catchments with catchment: cultivated area ratios of 1:1 and 1.25:1 and contributing aprons with 7, 10, and 15 per cent slope gradients was determined near Dera Ismail Khan, Pakistan. Plots with 1.25:1 ratios produced more forage and had more cover than plots with 1:1 and 0:1 ratios. Planted plots produced more forage and cover than sown plots. Ghorka (*Elionurus hirsutus*), blue panicum (*Panicum antidotale*), and buffel (*Cenchrus ciliaris*) grasses produced similar forage and cover; and in all cases this was higher than khev grass (*Sporobolus helvolus*) production and cover.

KEYWORDS: water harvesting/ forage production/ runoff cultivation/ Pakistan

Suleman, S.; Wood, M.K.; Shah, B.H.; Murray, L. (1995). 'Development of a Rainwater Harvesting System for Increasing Soil Moisture in Arid Rangelands of Pakistan.' In *Journal of Arid Environments*, 1995, 31: 4, pp 471-481. Las Cruces, New Mexico, USA: Department of Animal and Range Sciences, New Mexico State University

This paper describes the effects of water harvesting on the availability of soil moisture and affects on soil erosion during an experiment. It is stated that micro-catchments of 4-5 m in length with 7-15 per cent slopes increased soil moisture by 59, 63, and 80 per cent at depths of 0-15, 15-30, and 30-45 cm, respectively. Soil moisture increased in late summer and in late winter when precipitation is greatest. Rill erosion increased with micro-catchment length and gradient, with erosion volumes of 14.9-26.3 litres from areas of 120 and 150 square metres.

KEYWORDS: rainwater harvesting/ rangeland development/ micro-catchments/ Pakistan

Tang Chaoshuang and Zu Zhenghua (1998). 'The Utilisation of Rainfall Water In Xuzhou City and Its Contribution to the Sustainable Development of Agriculture.' In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 16-21. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper describes a very interesting and extensive system of rainwater use in Xuzhou city, e.g., interconnected contour ditches, gutters, and water-catch pits built at different altitudes in order to retain water efficiently. This interconnected water utilisation system looks like many melons clinging to a long vine. The local people are also using many water-saving irrigation methods such as sprinkler irrigation, sip irrigation, and the replenishing irrigation method.

KEYWORDS: rainwater utilisation/ efficient irrigation systems/ China

Tianxing, Z. (n.d.). 'Exploitation of Water Resources in Tibet.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 72-76. (Unpublished).

This paper describes the geographical characteristics of the Tibetan Plateau. Some measures for water resource development established in the area are discussed and these are irrigation channels and ditches to irrigate 93,000 ha of cultivated land and 200,000 ha of pasture land; about 5,000 reservoirs and ponds with storage facilities for 320 million cubic metres to irrigate about 13,000 ha of cultivated land; and underground dams in areas where there is a shortage of surface runoff and where it is rich in groundwater to raise the underground water level upstream from the dam.

There are more than 1,000 high mountain lakes. Many of these are being used for irrigation. Water storage tanks have been constructed for domestic and irrigation uses. At some places, in Shannan and Rikeze Prefectures, fish-scale pits have been dug to collect runoff for plants.

KEYWORDS: Tibetan Plateau/ reservoirs and ponds/ irrigation in mountains/ Tibet

United Nations Environment Programme / Tycooly International Publishing Ltd. (1983). Rain and Stormwater Harvesting in Rural Areas, 238pp. *Water Resources Series*, 5. Nairobi and Dublin: United Nations Environment Programme / Tycooly International Publishing Ltd.

This book describes the prevailing rain and storm-water harvesting systems in Africa, Asia, Australia and the Pacific, Central America, China and the Middle East for both domestic and agricultural uses. There are many illustrations of water-harvesting techniques and practices suitable for mountain watersheds and deserts. No design procedures or mathematical calculations are given. Potential water-harvesting sources such as dew, mist, and snow are also discussed.

KEYWORDS: water management / water storage / water quality / water supply

Wang Wenyuan and Jia Jinsheng (1998). 'Rainwater Utilisation and Sustainable Agricultural Development'. In *Proceedings of The International Symposium and Second Chinese National Conference on Rainwater Utilisation,* pp34-41. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

The paper emphasises the sustainable use of water resources for sustainable agricultural development. The lowering of the groundwater table as a result of overexploitation was a matter of concern as were seawater intrusion into coastal areas and the drying up of inland rivers. Moreover sinking deep wells means rejecting middle and shallow wells, causing economic loss to farmers. A rejection rate of 10 per cent per year for wells was reported from the North China Plains. Over-extraction of groundwater in urban areas is resulting in lowering of the water table at a rate of three to five m/annum. Continuous decline in the water table could cause the surface of the earth in the region to sink, and this may result in damage to buildings on the earth's surface. Statistics about areas subject to sinking and seawater intrusion are also given. Miniature rainwater catchment projects carried out by families are thought to play a key role in providing water for people and livestock.

KEYWORDS: sustainable water use/ groundwater depletion/ agricultural development/ China

Wang Yingjun and Zhang Lixia (1998). 'The Development of Water-Saving Agriculture – On the Utilisation of Rainfall and the Sustainable Agriculture'. In *Proceedings of International Symposium and Second Chinese National Conference on Rainwater Utilisation,* pp 147-154. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper discusses the strategies and technologies adopted to develop agriculture in Hebei province,China, by combining organic, engineering, agronomy, agricultural machines, and advanced and new technology. The major emphasis is on using demonstration sites. It is projected that by the year 2000, three million *mu* (15 *mu* = 1 ha) of water-saving demonstration areas will be completed to facilitate the extension of water-saving technology on to 13,000,000 *mu* and by the year 2010 the whole province will be under water-saving irrigation on farm land.

KEYWORDS: agricultural development/ water saving technologies/ China

Wang Zhiping, Zhang Wanjun, and Yang Yonghui (1998). 'Consideration on Rainwater Catchment and Utilisation of Sloping Field In China.' In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation,* pp 110-117. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper presents methods of managing soil and water resources in water deficient areas in the mountains, e.g., tillage practices such as contour tillage, field ditches, and ridge culture. Minimum or no tillage can intercept rainwater, decrease evaporation, and increase use of rainwater. Compared with along the slope tillage, contour tillage decreased runoff by 29 per cent, soil erosion by 79.9 per cent, and yields by 26.7 per cent. Engineered rainwater catchment systems, e.g., constructing small reservoirs, terraces, ditching slopes, digging deep wells, and building fish-scale pits, help sustain rainwater use. Design and construction processes for typical rainwater catchment systems are also described.

KEYWORDS: water management/ water scarcity/ land development/ rainwater catchment systems/ China

Wu, F. (n.d.). 'Micro Water Harvesting Works in Gansu Province, China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp34-37. (Unpublished).

This article gives a brief progress report of rainwater harvesting and its use in arid and semi-arid area projects carried out in Gansu Province, China. From 1989 to 1994, water-harvesting works were built by 27,900 households, some 2.385 million square metres of rainwater-harvesting catchment of cemented ground surface and tiled roof and 22,000 underground cisterns with cement plaster were completed. This solved the drinking water shortage problem for 141,600 people; 43, 000 horses and cattle; and 139,000 pigs and sheep.

A famous '1-2-1' project was launched in the province and it resulted in each household having 100 square metres of hard ground catchment for collecting rainwater, two underground cisterns with cemented plaster walls, and one *mu* (15 *mu* = 1 ha) of cash crops in the courtyard. 'A Guidebook to Rainwater- Harvesting Techniques' was published to guide the construction work. About 200,734 local technicians were trained. The project work was undertaken in 2,018 villages of 27 counties in the province. Through this project, drinking water was provided for 1,310,700 people and 1,187,700 livestock and 117,200 *mu* of courtyard cash crops were irrigated. The project has also saved 22.14 million working days for transportation of drinking water since 1990, because of the construction of rainwater-harvesting work. Harvesting 10.686 million cubic metres of runoff by the project reduced 2.93 million tonnes of soil loss per year.

According to the paper, application and extension of rainwater-harvesting techniques were the only way to overcome the shortage of water for drinking and irrigation. The project was extended: i) area wise, ii) in terms of technical practices, and iii) in terms of the objective which was broadened to irrigate 250 million *mu* in the province during the ninth five-year period.

KEYWORDS: water harvesting/ arid and semi-arid /China/ underground cisterns/ '1-2-1' project/ drinking water supply

Xinbao, Z. (n.d.). 'Water Harvesting Works in Liangshan Prefecture of Sichuan Province, China.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 130-135. (Unpublished).

This paper gives the background history, achievements, and benefits of water- harvesting measures carried out in Sichuan Province, China. By August 1996, 163,854 underground cisterns were completed in Liangshan Prefecture.The total storage capacity is 594 million metres. These structures can irrigate 23,000 *mu* of rainfed land and supply sufficient drinking water for 60,000 people and 90,000 cattle during the dry season. Because of these water-harvesting works, the gross product of the prefecture rose by 89 million *yuan* and farmers' incomes increased by 64 million *yuan* per year.

KEYWORDS: rainwater harvesting/ drinking water supply/ irrigation/ China

Yong, L. (n.d.). 'Application and Spread of the Underground Cistern Irrigation Techniques for Poverty Relief in the Southern Ningxia Mountain Region.' In Chalise, S.R.; Pradhan, P.; and Xinbao, Z. (eds) *Water Harvesting for Mountain Households in the Hindu Kush-Himalayas*, pp 44-46. (Unpublished).

This paper describes how underground cistern irrigation was used to alleviate poverty in the Southern Ningxia mountain region. Approximately 61 per cent of the people were living below China's poverty line definition standard in the region. Soil erosion and drought were common. The average rainfall is 300-500mm. The combination of traditional rain-field cultivation techniques with efficient irrigation cultivation techniques was found to be very promising and was considered one of the key measures for poverty relief in the region by the year 2000. Fifty-four thousand sets of underground cisterns for irrigation were constructed between 1993 and 1996, and 60,000 more were planned for 1997.

Water melons, vegetables, potatoes, fruit trees, tobacco, maize, and wheat were irrigated using a combination of plastic mulching and underground systems. A guidebook entitled 'Underground Cistern Water-saving Irrigation Techniques in Arid and Semi-arid Areas' describes the basic method.

On a rain-irrigated field treated with plastic membrane mulch, one seedling of maize needs 0.5 litres of water in spring and another 1-1.5 litres,of water for the rest of the growing season. The total amount of water needed for irrigation is 10-15 cubic metres per year for one *mu* (15 *mu* = 1 ha) of land with a mean yield value of 594 *yuan* (in 1996). Traditional ideas about land irrigation have changed to crop irrigation. In order to reduce siltation in the cisterns, farmers try to protect vegetation in the catchment in order to reduce soil erosion; this in turn protects the environment.

Demonstrations proved to be very helpful for application and spread of the measures used. Farmers were convinced of the benefits by demonstrations and became willing to build their own underground cisterns.

KEYWORDS: underground cisterns for irrigation/ high-value crops/ plastic mulching/ China

Yu-Si Fok (1998). 'RWCS Development Guidelines: A Bridge for Private and Public Sectors' Partnership'. In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp10-15.. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper presents the partnership approach to formulating RWCS' development guidelines by local authorities to be followed by private people. It is suggested that legislators always exercise the affordability principle to evaluate a bill that they introduce and for which they wish to secure widespread compliance. In general, five per cent of the annual income was considered an affordable price to pay for RWCS. The following guidelines were suggested for Hawaii (1) consider suitable roof catchment areas and storage capacities, (2) recommend contamination safe construction materials, (3) recommend filter systems, and (4) recommend a maintenance programme for RWCS users to follow.

KEYWORDS: water harvesting/sustainable development/runoff/ China

Zhao Wenyuan and Li Yuanhong (1998). 'Comprehensive Allocation of Rainwater Resources- Combining the Activity of Rainfall Catchment for Supplementary Irrigation with the Soil and Water Conservation.' In *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation* pp 365-373. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

This paper compares the economics of different techniques of rainwater catchment and storage development. It recommends construction of check dams in gullies for storage of water as a more economical approach than construction of cellars or cisterns. Similarly, use of 0.008 mm thick plastic film on fallow land is recommended as being more economical than concrete catchments. The annual rainfall collection efficiency of plastic film was 80-84 per cent and runoff could be promptly produced with 0.5mm rainfall.

KEYWORDS: economics of rainwater catchment/ plastic film catchment/ concrete catchments/ China

Zhu Qiang and Liyuanhong (1998). 'On Rainwater Catchment and Utilisation'. *Proceedings of the International Symposium and Second Chinese National Conference on Rainwater Utilisation*, pp 275-282. September 8-12, 1998 Xuzhou, Jiangsu Province, China. (Unpublished).

The paper describes the advantages of rainwater use, definition of rainwater catchment utilisation, types of rainwater collection, and storage subsystems used in Gansu Province, China.

Rainwater use (RWU) can provide a reliable means of providing water to areas short of surface and groundwater and solve the problem of water shortages effectively. In Gansu, the '121' RWCU project solved the problem of drinking water shortage for more than 1.2 million people and their livestock in one and a half years. The project worked well even in a year that was the driest in 60 years. RWU facilitates poverty alleviation and social and economic development. The input per capita is only a half to a fifth that of a conventional project. No government input is needed for operational charges. The cost of RWCU water is only one sixth to one eighth that of a long distance haul by truck. Loans for RWCU-irrigation systems can be returned within four to five years. Decrease in runoff due to water exhaustion by RWCU will only be 0.1-0.5 per cent of the total river flow. The different types of rainwater catchments include rooftop, concrete lined surface, cement-soil lined surface, plastic film-both exposed and soil covered, compacted soil, and road catchment. The storage subsystems include water cellar, water kiln, water tank, water jar, pond, and reservoir. Rainwater development has widened the field of water resources from the past practices, which relied on surface and subsurface water, and will help to solve water shortage problems.

KEYWORDS: rainwater utilisation/ water harvesting/ '121' project/ China

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Participating Countries of the Hindu Kush-Himalayan Region

Afghanistan

India

Bangladesh

Myanmar

Bhutan

Nepal

China

Pakistan

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