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
List of Participants

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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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India


Bangladesh


Myanmar


Bhutan


Nepal


China


Pakistan

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