

**Proceedings of the  
Ninth International  
Rain Water Catchment Systems  
Conference**

**Petrolina, Brazil**

**9-9 July 1999**

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# 1 STRATEGY FOR RAINWATER UTILIZATION IN THE NEXT MILLENNIUM

## 1.1 Trends in Water Demands and the Role of Rainwater Catchment Systems in the Next Millennium

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### Abstract

The world's population has been constantly increasing and so has the water demand. However, global freshwater supplies are limited to a finite 2% of the total available water. The main aims of this presentation are to analyze global population trends, to identify the areas of major water use, to propose ways and means of reducing consumption and to appraise the potential for development of rainwater catchment systems in the next millennium.

On analysis, it is noted that demand is largely dependent on the changing requirements in the domestic, industrial and agricultural areas. Other factors that influence water demand are the ease with which it is available and its price. Population growths influence demand rates and, though populations will increase, rate of growth will decrease. Worldwide water demand has increased six fold between 1900 and 1995 though population has only doubled.

However, almost 70% of water demand is from the agricultural sector. Another phenomena that will have a great impact is the proliferation of megacities, where urban populations will predominate. By 2025, the population in these megacities is expected to double to 5 billion. That means two thirds of the world's population will be living in megacities out of which 90% will be in developing countries.

With the prospect of an escalating water demand, the search for augmenting supplies will be one of the major worries of humankind in the next millennium.

The finite volumes available have to be managed optimally and it should be ensured that there is no friction between countries due to scarcity of water.

Water use has to be cut down with special emphasis on agricultural practices.

With the emergence of quite a few megacities, there should be large urban populations and correspondingly rapid increases in water demand in the

industrial sector. These urban populations will be sprawled over the megacities and are bound to encroach on catchment areas. As the urban population

will be quite substantial, particularly in developing countries, the catchment areas will be subjected to intense pollution. This will call for adopting effective measures to curb pollution and, as practiced in water-scarce Singapore, to extensively utilize urban catchments.

With high-intensity urban populations, there are bound to be large paved and roof areas which are ideal for rainwater harvesting. Besides, medium-sized catchment areas in educational institutions, airports, army camps, etc. can be fruitfully utilized for developing individual schemes and the collected water applied for potable and non-potable uses. These smaller schemes should, preferably, be integrated with existing conventional water supply systems.

The harnessing of water in megacities and the surrounding urban areas by utilizing appropriate rainwater catchment systems should alleviate, to a large extent, the future water demands.

## 1.2 Division Study of Rainwater Utilization in China

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### Abstract

During the last two decades, there has been a dramatic increase in the application of rainwater catchment systems for domestic water supplies and agricultural irrigation, especially for rural areas in developing countries. Tens of millions of systems have been constructed worldwide, and interest in these is continuing to grow, even in urban and industrialized regions. An old technology is gaining popularity in a new way. Rainwater collection will play an important role in solving the water shortage problems in China. This study analyzes those areas most suitable for rainwater catchment in China and presents the ranking of fitness for rainwater catchment in China and its further development in the near future. A GIS is used to help identify and list the potential areas of rainwater catchment throughout China.

## 1.3 Hawaii Rainwater Catchment Systems Development: Draft Guidelines

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### Abstract

The objective of this paper is to present a draft of Hawaii Rainwater Catchment Systems (RWCS) Development Guidelines for the conference participants and the readers of this paper.

The contents of this paper are (1) the present research results of our investigations as outlined in the USGS Collaborative Research Project (09/01/97 to 08/30/99) to form the basic approach of the RWCS development guidelines. (2) To assess the abilities of RWSC users to comply the items that have been proposed in the 1994 Hawaii House Concurrent Resolution no. 214, and (3) to show the Draft Hawaii Rainwater Catchment Systems Development Guidelines which may be adopted by the public sectors to regulate RWSC development and management.

## 1.4 Sri Lanka: Problems and prospects of rainwater catchment for the 21st Century

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### Abstract

Though Sri Lanka receives an annual average rainfall of 1,400 mm, 70% of the rural population is without clean drinking water. With a projected deficit for growing future water demand due to population growth as well as industrial and agricultural use, Sri Lanka's intention of providing clean drinking water for all by the year 2010 appears to be bleak.

Rainwater harvesting as a rural water supply option is a recently introduced technology in rural Sri Lanka. It has been accepted and adapted by many households where other water supply option failed due to technical or financial reasons. The Rainwater Harvesting programme was implemented on a 80% grant and 20% equity. The equity contribution was mainly in terms of labour and house guttering and down pipes. The latter components could be as high as 30% depending on the roof area.

The high cost of a unit compelled the programme to be subsidy driven. This approach, though financially appealing, threatens its own sustainability. Besides this problem, the “project approach” adopted by implementers, limited the programme to a construction phase. While mastering the technological component, awareness and management of the systems were left to the beneficiaries. This resulted in poor maintenance of systems leading to contamination and inadequate water. As a consequence, average water security was only up to 43% even by those owning rainwater harvesting systems. Less than 10% of the households used rainwater for drinking, indicating a dislike or mistrust for the quality of rainwater.

In the next millennium the major efforts will be on promoting rainwater harvesting on a “need base system” with an open market orientation. The focus will be on awareness creation on maintaining quality of water, managing the system as a complete water supply unit and cost reduction of rainwater harvesting units.

## 1.5 Water Potentials in the Brazilian Semiarid Zone: Perspectives for an Efficient Use

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### Abstract

In the central region of the Northeast, yearly rainfall is very irregular and varies between 500 and 800 mm/year. These meteorological conditions combine with the prevalence of a geological base formed by underground crystalline rock and practically impermeable, resulting in temporary rivers and semiarid soil conditions in about 10% of the national territory.

The vision of permanent rivers gives us the idea of abundance, while the temporary rivers of the Northeast leave us with the impression of scarcity. It needs to be emphasized that ideas of abundance and scarcity related to visions of permanent or temporary rivers, are as wrong as the geocentricism based on the vision of the sun's motion from one end to the other end of our horizon.

In reality, the physical and climatic conditions predominant in Brazil's Sertão (arid and remote interior) in the Northeast, can make life difficult, demanding more diligence and more rationality using its natural resources in general and water in particular, but they are not responsible for the widely spread and tolerated poverty patterns. What is missing most in Brazil in general and in the Northeast in particular, is not water, but a prevailing cultural pattern increasing confidence and increasing the efficiency of public and private organizations dealing with water questions.

The main goal of this paper is to refuse the physical and climatic determinism, which has served as justification for a culture of a water crisis in the world as well as in Brazil, as well as the draught culture in the Northeast.

## 1.6 Rainwater Harvesting Possibilities and Challenges in Kenya

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### Abstract

This paper examines the possibilities and challenges of rainwater harvesting in both rural and urban areas of Kenya. The problems of water shortage in urban areas and the high costs of developing new surface water sources, the scarcity of ground water supplies in Arid and Semiarid Lands (ASALs) and the unmanageable operation and maintenance costs of large piped water supplies are alarming. Therefore the willingness of the people, particularly in arid and semiarid areas, to embrace low cost initiatives like rainwater harvesting. The solutions suggested emanate from the grassroots community projects, the authors experiences in the water sector as an engineer and recommendation from household rainwater harvesting workshops.

## 1.7 Rainwater Catchment in Nepal: An Answer to the Water Scarcity of the Next Millennium

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### Abstract

For the past two decades, provision of safe drinking water facilities for people has been given high priority by both government and non-governmental agencies. Water has been brought closer to communities thus saving peoples' time and energy.

Catchment and utilization of the tremendous natural rainwater sources would be one of the right choices in Nepal's present context. Advantages of utilizing rainwater could be summed up: Women and children benefit first, quality of rainwater can be maintained with simple and minimum efforts, catchment systems are independent on a household level, simple construction and easy maintenance, low environmental impacts, reduction of soil erosion and flood hazards by intercepting roof run off and improvement of the ground water table due to reduction in abstraction.

## 1.8 Sustainable Water Resources Management in Arid and Semiarid Regions of the World: A Case Study in Iran

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### Abstract

Water tension is growing with the growing population of the world. The demand for healthy and adequate food in any sustainable development is among the most important sustainability indexes. In this context, water resource management plays a very important role. At the present time, most of the countries in the Middle East and North Africa are under water tension. In a sustainable development, a sound management of water resources is crucial in the socio-economical development of these countries in these regions.

The objectives of this paper are 1) to review the present state of water resources management and water tension in the Middle East and North Africa, 2) to review the water resource management in

Iran, 3) to discuss some case studies in the central desert arid condition of Iran.

The definition of sustainability with regard to arid and semiarid conditions is discussed here. However, sustainability as used in the environmental policy and research arena is indeed a complex issue. In general, sustainability even on a local level has to address and relate to global issues. With the advances in technology, the water utilisation has boosted the underground water resources. The sustainability of the present state of utilisation with the emphasis on the groundwater resources could be very questionable. In the Middle East, for example, Syria, Iraq, Lebanon, Jordan, Israel and the Occupied Territories (The West Bank and Gaza) have a combined population of nearly 42 million. Of these people, an estimated 41,5% rely on transboundary streams and 52% utilise springs, wells and rivers supplied by local precipitation. The remaining 6 % turn to water pumped from deep wells. At the present time these water supplies are being taxed to their limits.

## 2 WORDWIDE EXPERIENCES OF RAINWATER CATCHMENT SYSTEMS

### 2.1 Promotion of Rainwater Catchment in Southern Africa

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#### Abstract

Southern Africa is a drought prone region, and has suffered two severe droughts in the last 10 years. However, the use of rainwater harvesting in Southern Africa, even as a supplementary source of water is not generally promoted by government policies and practices in the region.

#### Regional Rainwater Harvesting Programme

A programme to promote the use of rainwater harvesting, for both domestic use and crop production, has been initiated by 2 South Africa based organisations, The Mvula Trust, a large water and sanitation NGO, and the Disaster Mitigation for Sustainable Livelihoods Project (DiMP), based at the University of Cape Town. The programme is one of three disaster mitigation/risk reduction initiatives being promoted by DiMP with support from the Department for International Development, London.

#### Goals and Objectives of the Programme

The goals of the programme are

To influence community water supply policy and practice in Southern Africa, towards the increased use of rainwater harvesting techniques.

To encourage best practice in the implementation of rainwater harvesting initiatives.

The focus of the programme is on development organisations directly involved in project implementation.

The participating countries are Namibia, Botswana, South Africa, Mozambique, Zimbabwe and Zambia.

#### Rainwater harvesting in the region

Most rainwater harvesting activity in the region is being promoted by the NGO sector. Domestic rainwater harvesting activities, using above and below ground storage, has been promoted in

Botswana since the late 60s. In Zimbabwe, a few NGOs have successfully introduced rainwater harvesting for crop production with small farmers in a few pilot areas. Rainwater harvesting is traditionally practised in several areas in Mozambique, and NGOs are promoting improvements to existing techniques. In some areas in South Africa, particularly the Eastern Cape, households use galvanised iron tanks to collect water from roofs with little external support. In Zambia, the Ministry of Agriculture and Forestry, together with NGOs, supports the construction and rehabilitation of small dams and weirs for small-scale irrigation and water for domestic use.

### **Organisation of the programme**

The programme will run at two levels. Regional activities, to be held throughout the duration of the programme, will be attended by representatives from all participating countries. These will consist mainly of workshops and planning meetings.

In each country there will be a country programme. One of the main activities will be the evaluation of existing rainwater harvesting projects in that country. In addition, there will be workshops that will often mirror the regional workshops.

The approach is to encourage knowledge and skills among development organisations, and to advocate rainwater harvesting at a policy level.

### **Activities**

A 3-day regional workshop has been held in Zimbabwe, and a second workshop is planned for September 1999. Country programmes are currently being planned.

## **2.2 Considerations for developing guidelines for rainwater catchment systems in the U.S. Virgin Islands**

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### **Abstract**

The United States Virgin Islands (USVI) is one of the few areas in the world where harvesting of rainfall contacting roof surfaces and subsequent storage of this water is required by law. High construction costs as well as standards of living with high demands for potable water, require that the mandated rain harvesting systems are designed, constructed, operated and maintained as efficiently as possible. The USVI has collaborated with the Federated States of Micronesia (FSM) to compare design practices that are utilized in the USVI and FSM. The USVI and Hawaii also collaborated on an examination of legal, economic, and institutional factors affecting rainwater systems in Hawaii and the USVI. These collaborations reveal that much is to be gained through detailed examination of practices and standards for rainwater harvesting systems that evolved independent of each other but with the same primary goal. While the long and many experiences with these highly developed systems in the USVI provide the other countries with options for future courses of actions, the USVI can gain much by the fresh and novel approaches taken by these countries in order to improve its rainwater utilization practices.

## **2.3 Rainwater Catchment in the Loess Plateau of Gansu, China and its Significance**

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### Abstract

China has been facing serious water shortage problems causing great economic and environmental losses. Water conditions are even worse in the Loess Plateau of Gansu in the Northwest and North of the country where runoff and groundwater are very scarce. Agriculture in this region relies mainly on rain and large sections of the population have suffered from lack of water for centuries. This is one of China's poorest areas. To promote social and economic development and to improve peoples' lives, it is essential to change water conditions. The only potential water source in this area is rain. Starting in 1988 efficient rainwater harvesting techniques had been tested. From 1995 to 1996, the local government implemented a "121" rainwater catchment project, providing 1.2 million people with access to drinking water. A follow-up rainwater harvesting irrigation project has been carried out to change the basic agricultural conditions in the area. The Gansu experience shows that rainwater catchment and utilization can provide an effective means to alleviate poverty and a breakthrough for farming in arid zones.

## 2.4 Ancient And Contemporary Water Catchment Systems In Mexico

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### Abstract

Mexico is rich in ancient and traditional technologies (dating back to the Aztecs and Mayas) on natural resources management; however, a growing demand for water and increasing costs of water supply for domestic use and agriculture production are resulting in a need for Mexicans to maximize the use of diverse water supplies.

In the near future it will be necessary to reinforce programs and projects to face the increasing demand for water and to avoid serious social problems.

Mexico, a country with 200 million hectares, an average annual rainfall of 700 mm and a population of 100 million people, has 1 400 000 million m<sup>3</sup> water from rainfall. This gives an annual average of 14 000 m<sup>3</sup>/person, enough for domestic use and agriculture production.

Currently different water catchment systems are used in Mexico: 1) for domestic use (water collection from roofs and paved land surfaces) and 2) for agriculture production (microcatchments, contour ridges, trapezoidal bunds, permeable rock dams, water spreading bunds, contour stone bunds and others).

## 2.5 Rainwater Utilization and Its Prospect in the Taihang Mountains, China

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### Abstract

Based on the experiments carried out in a typical watershed, I will summarize the main rainwater utilization techniques in the area of the Taihang Mountains. I am also discussing the impact of rainwater utilization on the hydrological cycle. In addition, I am analyzing the potential and prospect of rainwater utilization in the Taihang Mountains.

## 2.6 Experiences Gained in the Development of Rainwater Catchment in Tanzania

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### Abstract

As is the case in many African countries, rainwater catchment technologies have been used on a rudimentary level in Tanzania for a long time. Until recently, however, they have not made a significant impact in solving rural and urban water supply problems. Currently, various stakeholders are paying more attention to rainwater catchment as a means of supplementing the conventional water supply options such as piped water schemes, deep and shallow wells and springs. The shift in attitude among the decision makers has been influenced by the realization of the high potential of rainwater harvesting.

Over the past few years, efforts have been stepped up by the government as well as other organizations in developing rainwater harvesting systems throughout the country. The whole process started with awareness creation and sensitization on the importance and potential of rainwater harvesting technologies. Low cost demonstration rainwater harvesting cisterns are being constructed at strategic locations across country and people are being trained in the construction of low cost rainwater storage systems. Experience has shown that the demonstration tanks and other cisterns are playing a key role in sensitizing the people, who have responded by constructing rainwater catchment systems with their own resources.

## 3 RAINWATER CATCHMENT AND DROUGHTS

### 3.1 El Niño's Impact on Rainwater Catchment in Brazil's Semiarid Northeast

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### Abstract

This study uses the annual precipitation data provided by 88 weather stations in Brazil's Northeast. The yearly rainfall variations of each station were compared to the average climatic data of a 82-year period. For the period 1911 to 1992 the relationship between variations of yearly rainfall and the El Niño phenomenon was analyzed.

### 3.2 Potential Benefits of Tropical Seasonal Rainfall Forecasting for Rainwater Catchment Systems

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### Abstract

Much work has been done recently on interannual and seasonal rainfall forecasting for the tropics. Such forecasts are usually reliable at a regional or macro scale, but are less successful at the meso- or local scales, which are of interest for rainwater catchment systems. Methods are needed for the transfer of seasonal rainfall forecasts to the management of rainwater catchment systems and for evaluating their performance. This paper addresses the topic and presents an approach for transferring forecasts from regional to basin or local scales and an evaluation of their skill (as defined in the paper) for the Brazilian Nordeste. The results show that forecast skill decays as the scale becomes smaller and that forecasts are still of limited use at the local scale. On the other hand, they can be immediately useful for regional early warning applications, as well as for the management of larger rainwater catchment systems, such as those of large reservoirs.

## 3.3 Drought Criteria

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### Abstract

Rainwater catchment is an anticipatory response to drought. Catchment design requires a prudent definition of target drought. Target drought might be a normal dry season, two rainless weeks, etc. Definition is by both duration and depth of precipitation. Target drought is often a balance drawn from past hydrologic history, consequences of rainwater catchment system failure, social implications and public acceptance. Most of the numerous drought indices are inappropriate as catchment performance targets. This paper briefly reviews drought definitions and suggests an analysis for identifying proper rainwater catchment design criteria.

Analysis must anticipate the variety of meteorological futures that a catchment might experience. Stochastic analysis improves understanding of probable catchment behavior and the risks associated with alternative catchment designs. Drought Duration Depth Frequency analysis allows the time step for which a system is sized to be matched to the duration of drought. An example illustrates such assessment.

## 3.4 Modelling of Rainwater Catchment and Utilization on Farmsteads in Sipili, Kenya

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### Abstract

Undependable and erratic rainfall patterns, with frequent rainless periods within the rainy season in Sipili location, a semiarid area in Kenya, is the primary natural limiting factor to the rain-fed agricultural production potential of the area. Although the average annual rainfall of 600 - 800 mm would appear sufficient for one or two good crops per year, at times, the harvest is poor or there would be a total crop failure due to poor rainfall distribution. The level of supplemental irrigation mainly for horticultural crops is inadequate since farmers lack guidance on how efficiently harvested rainwater could be utilized for maximum returns.

A computer model was developed based on the mass balance equation to facilitate simulation of water utilization from different tank capacities meant to provide water for domestic use, watering two grade dairy cows and supplemental irrigation of a cabbage crop. The maximum cropped areas for different planting decades (10-day period) of the year up to crop maturity were determined for tank capacities of 50, 100, 150, 200, and 250 m<sup>3</sup>. The optimum cropped area for each tank capacity could be obtained when planting was done on the 14<sup>th</sup> decade. The maximum cropped area could be achieved when planting was done on the 2<sup>nd</sup>, 14<sup>th</sup> and 26<sup>th</sup> decades for 50, 100, and 150 m<sup>3</sup> tanks and on the 1<sup>st</sup>, 13<sup>th</sup> and 25<sup>th</sup> decades for 200 and 250 m<sup>3</sup> tanks. Such results would give farmers in Sipili and its environs an opportunity to strategize for the highest market prices of the cabbage crop or the highest crop yield.

### 3.5 Anticipatory Conservation Based Drought Management of Water Supply Reservoirs

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#### Abstract

A new methodology has been developed and evaluated for making long-term forecasts for the dry and wet period phenomenon. This study emphasizes the use of actual data as opposed to synthetic data. This is extremely valuable for the reservoir water manager dealing with the actual data as opposed to artificial data, which may or may not be materialized. Utilization of the method significantly improves storage reservoir management and also acts as a valuable tool in sizing the needed capacity of the existing or non-existing reservoir systems.

### 3.6 Serial Water Balance of Petrolina, Pernambuco—Brazil

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#### Abstract

In order to use the natural resources of a region, it is necessary to know the thermal and water conditions and their interaction. One way to find out about it is by realizing the climatic water balance. This balance is based on the calculation of pluvial precipitation and potential evapotranspiration. The objective of this paper was to realize the serial water balance in the region of Petrolina-PE. Daily data of precipitation and air temperature from Embrapa Semi-arido's agrometeorological station was used. The periods of water shortage and excess were defined and trends for the coming years were taken into consideration.

### 3.7 Rainfall Harvesting for Indigenous Health in Australia

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## Abstract

Australia is a dry country, particularly in the inland areas. The poor quantity and quality of water available to many Indigenous Australians living in rural and remote locations contributes to their poor health status relative to other Australians. Rainfall harvesting from the roofs of houses and buildings in Indigenous communities can provide a valuable source of potable water, but this harvesting is often inefficient. We report a study of two remote and diverse locations in areas where Indigenous Australians have water supply problems. The first is Giles in central Australia (25.04°S, 128.29°E) with a median annual rainfall of 119mm, and the second is Thursday Island in the Torres Strait (10.35°S, 142.22°E) with a median annual rainfall of 1718mm. We describe a means of correlating rainfall records with collecting roof areas, water storage capacity, house occupancy rates, and water consumption rates using a computer program. We determine the optimum match between these factors and the total collectable rainfall for the best, worst, and median years based on historical rainfall records for each location. This quantitative approach to rainfall harvesting could significantly improve the security of potable water supplies for many Indigenous communities in Australia, and thus contribute towards an improvement in Indigenous health.

## 4 TECHNOLOGY OF RAINWATER CATCHMENT SYSTEMS

### 4.1 Affordable Roofwater Harvesting in the Humid Tropics

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## Abstract

The relatively high cost per household of installing full domestic roofwater harvesting (DRWH) has resulted in its take-up being largely limited to areas of especially high water stress or where DRWH is subsidised. The paper discusses various ways of attaining satisfactory benefit:cost ratios in areas where DRWH is not the only water supply option, for example by adopting partial or seasonal supply and by minimising 'first cost' (generally construction cost) at the expense of raising subsequent costs. As water storage accounts for the bulk of expenditure on most systems, the paper then focuses on means of minimising the construction cost of storage tanks in the size range 1000 to 10000 litres. Best cost-cutting practices with respect to both surface and underground tanks are reviewed. An approach of separating the 'structural' and the 'water-proofing' roles of construction materials is proposed and applications of this approach to both sorts of tank are examined. The paper will particularly reflect experiences in South Asia and East Africa which are the geographical focus of an ongoing 4-country DRWH research programme funded by the European Union.

### 4.2 Abanbars as a Trustable Method of Water Harvesting

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## Abstract

Uneven spatial and temporal distribution of precipitation, high rate of evaporation, arid and semi-arid climate, evaporative geological formations such as gypsum and salt domes in southern as well as desert areas of Iran make it impossible to maintain the surface and ground water supply. The only

means to harvest water is century-old system called “abanbar”. The main objective of this paper is to investigate abanbars as a traditional method of water harvesting. I will discuss architectural, structural, geo-technical, hydrological, and hydraulic aspects of various types of abanbars and methods of constructing and maintaining them.

### **4.3 Sri Lanka's Experiences with Low Cost Extraction Hand Pump, Storage Cover, First Flush and Guttering in Domestic Rainwater Catchment Systems**

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#### **Abstract**

In Sri Lanka rainwater catchment has been traditionally used in the wet as well as the dry zones. Owing to the high cost of storage tank covers, extraction pumps, first flush devices and guttering, most systems remain under-utilised. In 1995, I supervised an action research study on the feasibility of rainwater harvesting under the World Bank assisted Community Water Supply and Sanitation Project.

This study resulted in incorporating rainwater harvesting into official water supply schemes. Since then, thousands of rural domestic water supply systems have been using rainwater harvesting. Among the technologies that have resulted are the low cost reliable storage tank covers made of ferrocement and clay bricks, a low cost low head extraction pump, made of PVC parts used to extract water from underground tanks, simple semiautomatic first flush devices and simple guttering. This paper describes these technologies, which will improve the quality of rainwater harvesting while keeping the costs reasonable. This will allow low-income communities for whom rainwater harvesting seems the best option for domestic water supply to apply this system.

### **4.4 Construction of Circular Rainwater Cisterns Using Metal Forms**

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#### **Abstract**

Technical volunteers of the Mennonite Central Committee (MCC), a Non-Governmental Organisation sponsored by the Mennonite churches of North America, have worked in the semiarid region of Northeast Brazil since 1968. In the late 1970's, they developed forms and a process for the construction of concrete cisterns as an appropriate technology for the catchment and storage of rainwater. The easy to use technology has been used to construct over 2,000 cisterns and line many hand-dug wells. There is no need for a professional mason or engineer to oversee the work; thus it is perfect for communities to use on their own.

The capacity of a 6 tube (ring) circular cistern is 15.000 L of potable rainwater, collected from rural buildings using eavestroughing. This amount is enough to supply a family of 8 for 250 days using 7.5 L per person per day. The advantage of this technology is that the force of the water is equal on the wall, unlike that of a rectangular cistern, where the water force is greater on the corners, often causing leaks. The construction of these cisterns uses a set of dismountable metal moulds which have a height of 50 cm, a diameter of 2.5 m and leave a wall spacing of 8 cm. The construction time period is seven days. The material costs are approximately US\$ 250.00, which may be entirely supplied by the

family, or partly subsidised. The labour for the cisterns is supplied by the families, using the work bee method where 2 to 3 families construct one family's cistern, and then together construct the next family's cistern using the same form, which is passed from house to house. This results in the family feeling a higher degree of ownership and responsibility for the cistern.

#### **4.5 Rain Collection as Water Source For Small Rural Communities in Chiapas, Mexico** (A case study: technical and social aspects for transferring of rural technology in Mexico)

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##### **Abstract**

In Mexico there are many small rural communities with serious water supply deficiencies. The introduction of alternative, low-cost technologies represents means of supplying water such as through fog and rain catchment. In the state of Chiapas, in southern Mexico, research is under way on rain water collection for human consumption. This research can then be applied in communities in the states of Chiapas, Oaxaca, Guerrero, Veracruz, Puebla and throughout Baja California. In Chiapas, there are 19,972 poor rural communities, 15,712 of which have fewer than 100 inhabitants. The lack of a constant water supply is most severe in the highlands of Chiapas where the population is made up mainly of indigenous groups. The communities are on mountainous terrain with a widely dispersed population. These characteristics combine to make the provision of public utilities, such as water, electricity and sewerage, difficult with conventional means.

The combination of potability and low cost makes rain collection a viable alternative for rural areas, weather permitting. The Mexican Institute of Water Technology and Chiapas University constructed a rain water collector (RWC) in Yalentay Chiapas. The rain water collector constructed in Yalentay consists of four parts: 1. Roof of aluminum, for collecting rain water, 2. Underground-cistern, divided in two tanks, 3. Filters, to improve the water quality and 4. Regulator tank.

#### **4.6 Evaluation of rainwater storage alternatives on San Andrés Island, Colombia**

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##### **Abstract**

We proposed and evaluated different options for a cistern of a "typical" house on San Andrés, Colombia, a very small island (27 km<sup>2</sup>) in the Caribbean facing Nicaragua's coast. On San Andrés, underground water supplies are very limited and the geologic conditions for storing surface water are not favorable.

We have carried out an economic study for the different storage alternatives to determine the most suitable material for the construction of the cisterns, be they concrete, modular, polyethylene or wood. 5 people inhabit a "typical" San Andrés house. We calculate a gathering area of 75 m<sup>2</sup> and an optimal cistern volume of 20 m<sup>3</sup>.

#### **4.7 Technical Presentation of Various Types of Cisterns Built in the Rural Communities of the Semiarid Region of Brazil**

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##### **Abstract**

In this paper I will give a brief description of the technical aspects of some types of cisterns which are currently being built successfully in the rural communities of the Northeast. I will describe the advantages and disadvantages of the construction of certain types of cisterns. I will also mention my own observations collected during the building and the use over several years.

The types of cisterns are the following:

1. Concrete plate cistern
2. Wire Mesh Concrete Cistern
3. Brick cistern
4. Reinforced concrete cistern
5. Lime cistern
6. Plastic cistern

#### **4.8 Development of Rooftop Rainwater Catchment System Design Criteria for Pohnpei State, Federated States of Micronesia**

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##### **Abstract**

This paper reports on the results of the University of Guam component of a three University cooperative research study funded by the US. Geological Survey Water Institute Program. The results of the University of the Virgin Islands and the University of Hawaii components will be reported in other papers contained in these proceedings. All three projects concentrated on problems encountered with rainwater catchment systems (RWCS) implementation in each island region.

The purpose of the University of Guam project was to develop and disseminate criteria to be used in the design of new or refurbishing of existing individual water supply systems for various islands in Pohnpei State, Federated States of Micronesia. The end product was a set of design curves and tables for sizing RWCS so that these systems can provide a continuous water supply even during the harsh drought conditions that affect this part of the world.

#### **4.9 Influence of Rainfall Amount and Distribution on Rainwater Catchment System Design**

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### Abstract

The analyses of rainfall characteristics form the core of the hydrological design of rainwater catchment system. Of importance are such aspects as rainfall amount, rainfall distribution, length of wet and dry spells, drought severity among others. The coefficient of variation, unlike the standard deviation, does not depend on the annual totals but only on the degree of variation between the monthly totals for each year. Rainfall amount and rainfall distribution are analyzed by calculating the probability of exceedence for each value according to a plotting position formula devised by Weibull.

The results indicate that in the hydrological design of rainwater catchment system, two aspects of rainfall are of paramount importance. These are rainfall amount and rainfall distribution. The hydrological design leads to the determination of the major parameters of catchment area and tank size. This study therefore serves to demonstrate adequately that rainfall amount influence catchment size while rainfall distribution influences the storage capacity.

## 4.10 Optimization of rainwater catchment systems design parameters in the arid and semiarid lands of Kenya

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### Abstract

It is evident from experiences in Kenya that rainwater could be the long awaited answer to water scarcity in the next millennium. However, some technical and policy hindrances need to be addressed. Lack of appropriate technical designs, among other factors, has led to low adoption of rainwater harvesting technology, especially in Arid and Semiarid Lands (ASAL), where rainwater is one of the most viable water supply. This calls for optimization of Rain Water Catchment Systems (RWCS) design parameters and formulation of comprehensive water policy. Therefore, to address this problem, the paper focus on the hydrological criteria for determining RWCS design parameters, especially storage capacity and catchment area, using historical rainfall records of Kibwezi rainfall station. Specifically, a design procedure for determining optimal design parameters and developing design curves is outlined. The mass curve analysis was adopted for the determination and optimization of the design parameters due to outlined inadequacies of most empirical formulae. The strength of the design procedure is the determination of optimal design parameters at various reliability levels of rainfall amount and distribution. The analysis of design parameters revealed that the catchment area and the storage capacity are affected by variations in rainfall amount and distribution respectively.

In addition, the paper proposes a procedure for incorporating rainfall distribution, which has been consistently ignored in the designs of RWCS. The proposed procedure involves adjustment of monthly rainfall by using rainfall distribution indices such that the monthly rainfall totals correspond to annual rainfall at a given rainfall reliability level. The adjusted monthly rainfall is subjected to mass curve analysis to determine the design parameters at various reliability levels. The selection of optimal design parameters is simplified by the development of design tables and curves from which the catchment area and storage capacity for a specific water demand can be easily obtained at various reliability levels. The paper concludes by proposing some recommendations to promote utilisation of rainwater, and adoption of RWCS technology in Kenya. Therefore, the developed procedure could enormously contribute to the adoption and implementation of optimal RWCS designs, and hence supplement government efforts towards meeting ever increasing water demand. The procedure could also be used to evaluate the reliability of existing RWCS.

## 4.11 The Sizing of Rainwater Stores Using Behavioural Models

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### Abstract

The collection of rainwater from roofs, its storage and subsequent use is a simple method of reducing the demand on both the public water supplies and waste treatment facilities. The capacity of the rainwater store is important because it affects both system and installation costs.

The rainwater store can be sized using one of three general types of model, namely, Critical period methods, Moran related methods and Behavioural models. This paper concentrates upon the use of behavioural models for the sizing of rainwater stores.

Behavioural models simulate the operation of a reservoir with respect to time. The operation will usually be simulated over a given period of time using a time step of a minute, hour or month. The operation of the store is simulated using either a yield after spillage (YAS) or yield before spillage (YBS) algorithm. This paper evaluates the accuracy of behavioural models using different time steps and different sizing algorithms applied to both large and small stores.

## 4.12 Determination of the Optimum Volume of a Cistern Applied to San Andres Island, Colombia

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### Abstract

In rural areas far away from urban centers and on the very small islands (less than 100 km<sup>2</sup>), where underground water is very limited and the geologic conditions for storing surface water are not favorable, rainwater harvesting is the only available alternative to supply drinking water. In my paper I will present a methodology to find the best storage capacity of a rainwater cistern taking into account the hydrological, harvesting and consumption variables. While small cisterns help to save water, big cisterns are cheaper.

## 4.13 Effective Application of First Flush Device to Improve Rainwater Quality

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### Abstract

Rain water harvesting helps to reduce the burden on other sources of water in the context of proper water resources development. Rainwater collected while using a first flush system enhances the quality of drinking water and considerably reduces water borne diseases. There are automatic and manual operated first flush systems for rainwater harvesting. The most suitable, technologically appropriate and tested systems for developing countries are being outlined.

#### 4.14 Barrier to the Effectiveness of Rainwater Catchment Systems

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##### Abstract

Guttering often is the weak link in the performance of a rainwater catchment system. Most of the time, collected rainwater is spilled before reaching the cistern. Problems range from gutter maintenance to its design. This paper addresses design issues, locally available materials and the relationship between rainfall intensity and roof area to gutter cross-sections area, shape, slope and length. Special consideration is given to aspects of gutter technology in developing countries.

The paper also recommends suitable measures for promoting rainwater harvesting techniques in drought prone areas of Uganda and other developing countries.

#### 4.15 An Assessment of the Damage Sustained by the Gareh Bygone Plain Artificial Recharge of Groundwater System in the Deluge of 1995

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##### Abstract

In Iran floods result in more than 200 deaths and US \$1 billion damage per year. The damage due to floods ranks second behind earthquakes. Floodwater spreading (FWS), particularly for the artificial recharging of groundwater (ARG), is a technique that could transform a curse into a blessing. The deluge of 1995, caused by 80 mm of rainfall during a 24-hour period, resulted in bringing an ARG system in the Gareh Bygone Plain (GBP), in southern Iran, into full operation. These floods, occurring at an interval of 50 years, cause considerable damage in the southern parts of Fars Province. Although the ARG systems are designed to withstand a once-in-every-15-year flood, the GBP scheme sustained very little damage. The flooding breached only 1% of the embankments and undermined about 19% of the chutes installed in the gaps. The cost of repairs and system maintenance are only 2.5% of the damage, which could have been inflicted on the properties, had it not been harnessed by the ARG systems. The overall government budget for prevention of flood-related damage is quite big and could be used better if there was a new flood mitigation strategy.

#### 4.16 Damming and Storing of Rainwater in Central Brazil

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##### Abstract

Concerned about the future of water and its quality, the city of Sete Lagoas, in the state of Minas Gerais, has been developing a project for 'Damming and Storing Rainwater.' The system has been in operation for four years in an isolated area. This area covers 70 ha and has 30 small dams.

In 1998 the idea of implementing this system on a major scale became more definite. It was decided to cover the whole micro-area of Ribeirao Paiol with small dams. These small dams were installed in places with heavy rainfall causing erosion. The idea was to block the flow of rain water, minimizing its disastrous effects by keeping out sandy and polluting materials, such as soil, manure, fertilizers and others. These materials tend to go straight to the springs and wells causing condemnation, flooding and other damages.

Like a roof, the soil collects rainwater, concentrating it like a stream; barring it in successive small dams eliminates its damaging effects. After filling the first dam the overflow goes through a drainage ditch to the second dam, and thus on and on until it reaches the valley.

In all of Brazil's middle west the soil is mostly porous and deep. With a rainfall of 1000 to 1600 mm per year, the soil in dammed up areas functions like a storage sponge for filtered water. The main objective of the system is to load and unload the storage pond, adjusting water infiltration in the short time between rains. Much in the same way as numerous drenchings during a rain cycle increase the ground water level, filling the natural water tank of the soil.

The main purpose of the construction of small dams is to recuperate areas devastated by rain and turning spring water into a lasting good water supply. Other objectives are to promote renewal of the valleys, ease small draughts, allow second small harvests and the opening of fish tanks.

#### 4.17 Technologies for Enhancing Ground Water Recharge

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##### Abstract

In countries like India, with an ever-increasing demand for water, the importance of rainwater harvesting and groundwater recharge cannot be overemphasized. With this background in view, the laboratories of the Council of Scientific & Industrial Research have developed and demonstrated various technologies for the enhancement of recharge through various means. These are the use of injection bore holes in hard rock, recharge through tanks wells, siphon recharge, enhancement of run off through treatment of catchment with polyamine material use of chemical for control of evaporation and also for stabilizing and sealing of soil through hydrophobic chemicals, etc. This paper attempts to consolidate the experiences gathered in respect of the case studies in various rainfall regions with different soil characteristics.

#### 4.18 Micro-Minor Methods of Rainwater Conservation and Groundwater Recharge

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##### Abstract

This is a study of location specific rainwater harvesting techniques from the past to the present. To evaluate ancient methods of water harvesting/conservation, large scale experiments were laid out using essentially two modern methods: spreading and water injection. The spreading techniques comprised of slopes, trenches, ponds, percolation tanks, etc., whereas injection techniques comprised of augured piles, dug wells, injection of water through tube wells, roof water collection and pouring it into tube wells.

In an area of 250 hectares, slopes along roads, trenches in and around the cultivated fields of 2 to 3

hectares, small ponds in low lying areas, percolation tanks for small catchments were developed. Water recharge in the deep aquifer through such spreading techniques was found to contribute around 23 % of rainwater available for conservation. An innovative Indore technique was applied to abandoned dug wells by pouring in run off water. Round hole piles with a diameter of 22 cm and 2 to 3 m deep were augured and filled with pebbles and sand in places such as parking lots, gardens and empty areas. During the monsoon season when surplus clean water was available on the surface or in dug wells, water was injected in the tube wells up to a depth of 30 to 50 meters with the help of motor pumps. The deep aquifer accepted water to its full capacity. Abandoned tube well bores and dug wells were used for pouring collected roof water. All these injection techniques contributed 77% of artificially recharge ground aquifer.

The estimated average recharge index over a period of nine years was 2,25% more. Simultaneously the integrated techniques of water recharge were extensively adopted by several industrial units and became part of a national watershed programme. This shows the current relevance and cost benefits of micro-minor methods of water conservation and ground water recharge.

#### 4.19 **Underground Dams: A Pernambuco (Brazil) Experience**

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##### **Abstract**

During the past 7 years, NGOs as well as governmental agencies carried out many experiments with underground dams in the State of Pernambuco. Currently there are about 500 of these underground dams in operation, as well as another 500 built by technicians. The largest dams have a depth of 10 m and they can hold about 80.000 m<sup>3</sup>. This volume is large enough to assure provisions for up to 500 families, or provide irrigation for 15 ha. This paper deals with the potentials of this type of water reservation.

#### 4.20 **Improving Environmental Characteristics in a Wide Area Around a Flood Water Spreading System, “A case study”**

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##### **Abstract**

Soil is a huge place for reserving rainwater from where it can be released gradually and with the lowest water loss. In an area where the soil does not exist or the soil thickens is negligible, the water capacity of the soil is quickly replenished. In arid and semi-arid zones, the rain intensity is high and rain distribution is low. Thus enormous amounts of rain are lost as flooding. Water spreading systems give enough time to spread the rainwater and to infiltrate deep into the soil. The Gareh-Baigan Plane, situated in Southern Fasa, in Iran's Fars province, is an arid zone often affected by floods. The water spreading project was designed for an area of 2500 hectares with the purpose of increasing rainwater content in the soil, artificial recharge of groundwater and improving environmental aspects. The total area affected by the project is about 7500 hectare. Using computer image processing of aerial photos and satellite imagery data of the area before and after the project shows the following:

- increased cultivated area due to utilization of more water from the aquifer
- improved rangelands and forest area due to a higher water content in the upper soil layers

- reduced wind blown lands and more desertification control due to vegetation developments
- reduced soil erosion, due to flood control, in the lower part of the area
- a pleasant and natural place was created in an arid zone.

The remote sensing method allows consideration and distinction of the mentioned improvements. Application of such systems in arid and semi arid zones not only improve the water content of the soil, but also help to reduce the bad effects of floods.

#### **4.21 Rock Tanks, Dugouts and Riverbed Dugouts: Three Traditional Systems of Rainwater Catchment in the Brazilian Northeast**

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##### **Resumo**

In the Brazilian Northeast, a large area of approximately 900,000 km<sup>2</sup> receives a classification as being semiarid. In this region however, one does not find traditional water catchment systems typical of semi-arid regions, such as wells, cisterns, etc. This could be due to the level of technological development of the native population, prior to the arrival of the Portuguese colonizers, but also to the simple fact of lack of need. The semiarid Brazilian northeast has many humid areas, and neighboring areas have regular rainfalls. Large parts of the dry interior region have a short history of settlement by people of European origin, too short for the development of empirical spontaneous technologies.

A large part of the Northeast semiarid region has a crystalline sub-soil, highly adequate for natural water reservoirs of the “caldeirão” type, for the excavation of dugouts and for the construction of riverbed dugouts.

The caldeirão (rock water tanks): are natural holes in granite rock that, when excavated, represent excellent reservoirs for rainwater.

The caxio (dugout): weathering transforms the granite rock in such a manner that it may be dug manually, with relative facility, but that preserves a total impermeability.

The original measurements are 4.40 m. The construction of a dug-out is a task that takes various years and, has two separate parts, one may use first the water of the shallow area and continue to deepen it during the annual dry season.

Riverbed dugout: is constructed in the bed of one of the many streams and rivers. To avoid the riverbed sand from caving into the area, today it is common to construct, on a firm base, a brick wall, or concrete rings, to a level a little lower than the river or stream bed.

Access to water, a basic right of being a citizen.

The construction of independent water sources, under the control of the rural population, has demonstrated its effectiveness in the increase in the consciousness and civic activity, creating independence from the traditional rural powers that be, and has resulted in an increase in production in the rural area and a reduction in rural migration.

## 5 POLITICAL AND SOCIO-ECONOMIC ASPECTS OF RAINWATER CATCHMENT SYSTEMS

### 5.1 Peasants Attitudes Towards Participation in Floodwater Spreading Systems Development - The Case of the Gareh Bygone Project

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#### Abstract

The Gareh Bygone floodwater project has many positive effects on peasants' lives. Nowadays, the irrigated area in the plain is several times larger than at the beginning of the project. This enlargement has caused a steep increase in the income of the farmers and has new provided jobs. The number of livestock has decreased, while the harvested area has increased. By filling out 69 random questionnaires and by interviewing peasants, the necessary information about the Willingness To Pay (WTP) for developing and conserving the project was collected. Depending on each families interests in the project, their willingness to pay differs.

### 5.2 Rainwater Harvesting and Poverty Alleviation, Laikipia Experience

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#### Abstract

Kenya has a population of about 25 million people. The current water supply coverage is 42%. This means about 15 million Kenyans have no access to an adequate and safe water supply. This implies that a large section of these Kenyans are faced with not only a dehumanizing situation but also suffer severe social and economic consequences. In the 70s and 80s, the government constructed large water projects such as sinking bore-holes and large pumping and piping water schemes. These projects introduced huge management and organization problems and today many of them are no longer working. The Kenya Rainwater Association (KRA) was founded to bring together individuals and institutions wanting to face the challenge of low water coverage by utilizing rainwater. By using low cost technical options and building local capacity through community based organizations (CBOs), a lot was achieved.

This presentation describes 10 years of experience of rainwater harvesting activities, which were used as a catalysts for development to alleviate poverty and to promote economic and social well-being of rural people in the Nakuru district in Kenya.

### 5.3 Political and Socio-Economic Dimensions of Rainwater Catchment on the West Bank - Palestine

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#### Abstract

The major components in the Palestinian-Israeli political conflict since 1948 are the land and water resources; i.e., control and management of water. Because of the limited water resources and the land confiscated by the Israelis, many national and international Non-Governmental-Organizations are working together with the Palestinians to take care of their water needs. Within the political context, rainwater catchment is the only water source for the rural areas suffering from water shortage. In fact, 37% of the population of the West Bank live in areas without sustainable water supply systems, and 49% of the communities have no water supply systems.

The Palestinian Hydrology Group, together with other agricultural organizations developed a program to help people in rural areas to collect rainwater for both domestic and irrigation purposes. The program involves construction of concrete ponds and cisterns. Concrete ponds (with a capacity up to 2200 m<sup>3</sup>) are used to collect rainwater from roofs of greenhouses and direct runoff. The water is used to irrigate the surrounding land and the green houses. Cisterns (with a capacity up to 200 m<sup>3</sup>) are used to collect rainwater from the roofs of the houses. The program provides beneficiaries with technical and financial support. The beneficiaries from the program used to buy one cubic meter of water for about US\$5. Cisterns with a capacity of 150 m<sup>3</sup> can fulfill the domestic needs for an average of more than six months and save about 50% of the money allocated for water purchasing. Concrete ponds, used to irrigate uncultivated land or the green-houses, help in providing families with extra income. Besides, the socio-economic dimensions of the program, rainwater collection helps to prevent confiscation of Palestinian land by the Israeli authorities.

### 5.4 Building Cisterns in Campo Alegre de Lourdes, Bahia--Living with the Brazilian Semiarid Climate

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#### Abstract

On the eve of the 21<sup>st</sup> century, almost the entire rural population of Campo Alegre de Lourdes (Bahia) county, just like most everyone in Brazil's semiarid Northeast, lives under very precarious conditions due to the effects of the draught and the lack of water for humans, animals and agriculture.

Under these circumstances whole families are often forced to move to the next town or to other parts of Brazil. Those who decide to stay and to keep their farms and animals, often lead a life lacking many basics, sometimes going without drinking water and other basic necessities.

The official measures taken to ease the situation are often only temporary solutions. Nevertheless long-term solutions exist. The concept "alternative ways to live with the draught" is known as well as the experiences with water catchment carried out by the government organization EMBRAPA and NGOs such as CAATINGA and IRPAA.

We all know the reasons why government organizations have been incapable to deal with the phenomenon and the consequences of the draught. Therefore the farm workers of Campo Alegre de Lourdes decided to solve this problem on their own. In our paper, we will tell how these farm workers confronted this problem and the process they went through to solve it.

## 6 GENDER AND COMMUNITY RELATED ASPECTS OF RAINWATER CATCHMENT SYSTEMS

### 6.1 Alternative Loans for the Construction of Domestic Cisterns in the Semiarid Region of the State of Paraiba, Brazil

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#### Abstract

Since 1996 the Italian NGO Progetto Mondialita has been implementing an Alternative Loan Program, with Italian Cooperation for the construction of domestic cisterns in the semiarid region of the state of Paraiba. The overall aim of the Program is to raise the capacity for catchment and storage of drinking water in the rural communities.

We opted for the construction of cisterns due to their many positive aspects. Cisterns are the most appropriate reservoirs for the storage of drinking water.

During our two and a half years of activity, we organized and put in operation a Rotating Fund for the involved communities. So far we have been able to build 157 domestic cisterns, an average of more than 50 domestic cisterns per year.

Basically, the Program is an initial incentive- a lost fund investment - consisting of a basic amount of financial assistance, enough to support the first steps of building cisterns. The people from the community organize work parties to build their own cisterns. At the same time, they start to pay off the costs of the cisterns in small monthly payments. Once the initial investment starts dripping back into the fund through these monthly payments, other communities start to make their own construction plans.

Besides the obvious benefit of having cisterns, the project also gives employment to a technical assistant for 25 cisterns and turns into a tool for professional training within the communities.

After three years of activities, the Rotating Fund has proven to be totally self-sufficient, and could be easily implemented in other communities through the semiarid zones of Brazil.

### 6.2 Women in Community Communication in the Watershed

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#### Abstract

Communication is a vital element in working with watershed protection, rainwater catchment maintenance, or forest rehabilitation. Communication is, in fact, the heart of development work. It facilitates new understanding, new concepts and ideas. It bridges cultures, it encourages, as well as making people think and act. It could give new directions and enable people to move and leap or it could stifle them with fear, ignorance, and apathy. People cannot not communicate. Communicating means living.

This is the experience of a group of women doing rehabilitation work in two watersheds in the central part of the Philippines. These women held hands with the women in the community in order to forge the difficult part of convincing the whole community to participate in the work of protection and rehabilitation of two natural rainwater catchment basins, the headwaters of a major watershed on an island.

The learning of these women in communication and development is expressed in this paper. The learning dwells on the roles, time structure, hierarchical status and the prevailing mode of relationships of women, which had allowed them to experience the value of communication. This experience has an extensive influence in the forming of communication strategies (personal or organizational) to infuse change or development. For example, the effectiveness of a mother's role in child rearing is dependent on her personal communication strategies. A woman's prevalent role as a teacher at home, at school or in the community also demonstrates the effectiveness of communication. Nursing the sick, another popular role of women utilizes extensively communication not only at the physical level – both verbal and non-verbal, but also communication of empathy, sympathy, concern, caring, and other spiritual attributes.

Indeed, time is the essence, but for a woman, time is fluid and unconstraining. Time spent in nurturing, in nursing, in school, is not counted by the hours but by progress and intensity. Woman has learned and experienced that time, as a value, is not dominating but rather allows the leisure and the pleasure of molding and change. Many women have believed those men saying that in order to be productive, time should be precise and be allowed to control man. Many women of the cities have succumbed to such ideas but rural women are far from it. They have not reckoned time, yet they have accomplished much. This kind of valuing time (not simply called patience) has been a critical element in development communication.

In organizations, whether of social, political or economic in nature, women's status is generally not on top. More so for a mountain woman, she occupies the middle or even the lower middle or the bottom levels. She is not isolated, she always relates with people, identifies with others and feels with them. This experience brings into fore the mode of relationships with others. The woman experiences lateral or horizontal modes of relationship, and not authority-based relationship. The demands and quality of peer relationship and peer leadership require unique skills in communication different from that of a managerial or authority-based relationship. To get things done, the woman has to handle communication effectively, not just the use of power.

With this woman-advantage, women from a development organization touched base with the women in the watershed.

### **6.3 Community Management of Water Harvesting Structures**

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#### **Abstract**

Numerous projects have been implemented and successfully completed with the help of a funding organization. Much has been done in the field of rainwater collection for crops as well as domestic and livestock consumption. Thousands of kilometers of piping systems have been laid and water tanks, as well as structures for conserving water and dams were built.

But in reality most of these projects never function efficiently or breakdown completely once the donor pulls out.

The question is why? This paper discusses the question as to why this is happening in Kenya as well as all over the world.

### **6.4 Rainwater Collection: An Easy Way to Overcome the Chronic and Growing Shortage of Water of the Albanian Rural Family**

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### Abstract

Albania has abundant rainfall (722-2747 mm/year), but mostly concentrated in the rainy season (October - April). During the dry summers, water levels are often at a critical low. During the past 50 years, rainwater catchment has been used to irrigate 50 - 60 % of the land, but little has been done to supply clean, safe drinking water for the people. Among the 2800 villages only 450 (16%) have aqueducts. During the summer only 5-10 liters of water per capita /day are available in some villages. Since the current government seems to be unable to supply the rural population with access to safe drinking water, the NGO Rain & Rural Family was founded in 1997 to study the possibilities of promoting roof rainwater catchment. The study states that each house with a roof of 50-100 m<sup>2</sup> could collect enough water to provide 6 people with an average water supply of 60- 130 liters for 90 days. The cost to built a reinforced concrete cistern would come to 590.000 leke ( about US\$ 3,000). Rain and Rural Family aims to : 1) popularize the concept of rainwater harvesting, 2) inform the public about the tradition of rainwater collecting and 3) to establish rainwater collection as a national priority.

## 6.5 Rainwater Catchment: Women and Gender Participation in Zimbabwe

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### Abstract

Rainwater catchment and storage have been successfully utilized by people all over the world. Any form or size of container has been used to harvest and store water from roofs made of iron sheets, asbestos and grass thatch. Many systems of rainwater catchment have been designed over the years. These systems however can work well only when they are adapted to suit specific environments in which they are placed. Experience has shown that no one technical solution can be applied throughout one country. Technical solutions must be adapted to suit local environments and local financial resources and also suit traditional skills in construction and facility use behavior of the population. The following paper shows how these questions were solved in the towns of Beitbridge, Plumtree and Mberengwa in Zimbabwe.

## 6.6 Ask the People: Experience of Makong'endela: Rock Catchment Dam in the Masasi District, Tanzania

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### Abstract

There are many good people and organizations who wish to solve peoples' water problems. Such groups have very good ideas but in most cases they lack the approach to select the right source or project which can be sustained both socially and economically.

In most cases feasibility studies are done thoroughly only from the economic point of view, while the social aspect falls to the wayside. The question of what the community will think about it, is often not

realized until implementation or towards the end of the project.

This is the case of a rock catchment dam introduced at Makong'endela village in the Masasi district, in the Mtwara region of Tanzania. There is so much labor involved in it, it led villagers to believe that there must be a better and easier way of solving their water problems. Nevertheless, the government authorities have forced people out of their villages. At this point, the project is incomplete and the villagers are refusing to deal with water issues. This is a classic case where people should have been given alternatives and asked to come up with the solution that agrees best with them.

## **6.7 Caritas' Domestic Cistern Program for the Brazilian Semiarid Zones: A Simple Initiative With a Great Result**

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### **Abstract**

I would like to show the effect of small initiatives, such as the importance of domestic cisterns, developed by the Brazilian Caritas together with rural people in the Brazilian semiarid zones. This initiative started several years ago, but has been intensified since 1998. The techniques, dimensions, the most useful ways to make sure that the domestic cistern guarantees enough water, are already well known to the Caritas and the NGOS working in the region. The concrete plate cistern is one of the essential ingredients to live with the semiarid climate, allowing the catchment of good drinking water.

The basic principle for success is community organizing. And it's here where we want to point out what we consider essential: the politics of promoting life with the semiarid climate will only be successful if they go hand in hand with a participatory methodology and valorization of local customs and culture.

We know that all catchment, conservation and water use initiatives, as well as all the necessary political steps to promote a healthy and happy life in the Brazilian semiarid regions, including an agrarian reform and irrigation politics, will only be successful if they are implemented in a democratic fashion with the participation and the promotion of civil rights for all those who live in the region.

## **6.8 The Role of Women in Water Development**

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### **Abstract**

In rural areas of developing countries, such as Kenya, women understand the urgent need for improved accessibility to water sources. It is estimated that most rural women spent more than 80 percent of their time drawing, carrying, managing and using water. In most cases this water is inadequate and unsafe. About 67.5 % of the rural and 6.7% of the urban households have access to unsafe water sources. (CBS's Housing Survey 1994).

Most women may not be aware of water related diseases nor do they see a direct relationship between improved water supply and health, but once water sources become available, they quickly evaluate the benefits in terms of improved sanitation, personal hygiene, increased food security and reduced workload.

Clearly, women have much to gain from an improved water supply through rainwater collection. The additional time gained will ensure its sustainability, because the time saved can be used for income generating activities, such as growing more food crops, commercial activities, and promoting their family health.

## 6.9 Rainwater Catchment in Brazil's Rural Semiarid Tropics: A Grassroots' Approach

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### Abstract

During the past decade, NGOs and grass-root organizations working in Brazil's semiarid tropics have focused on rainwater catchment systems as an essential contribution to people's survival under the region's climatic conditions. Awareness about the possibilities of the semi-arid region had to be raised. The main necessities are adequate education at all levels, therefore organizations working in the Northeast dedicate most of their efforts on this aspect. The organizations not only teach appropriate technologies, but first speak about an appropriate understanding of the semiarid climate and then introduce rainwater catchment systems and look at the socio-economic and cultural conditions of the people involved. There has to be a political willingness to create an infra-structure such as access to land, animal raising, rain-fed agriculture, water supply, education, health service, streets and commercialization of local products. Once these aspects are taken into consideration, the future of the rural population in the Brazilian semiarid region will be more certain.

## 6.10 Food Security Through Rainwater Catchment

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### Abstract

Harvesting rainwater, from the rooftop and on the surface, has been part of Indian social and cultural life since antiquity. A wide range of hydraulic systems to suit diverse ecological regimes exist in the country. Ancient texts, inscriptions, local traditions and archaeological remains bear testimony to a rich tradition of rainwater harvesting. Some evidence of advanced water harvesting systems can be traced from pre-historic times as well. The Puranas, Mahabharata, Ramayana and various Vedic, Buddhist and Jain texts contain several references to canals, tanks, embankments and wells.

With the settling societies being largely agrarian, written texts are loaded with reference to irrigation systems. Kautilya, a minister of King Chandragupta Maurya (321 – 297 BC), gave vivid reference of irrigation with water harvesting systems in his historic politico-administrative treatise called the Arthashastra. Kautilya's treatise is often compared to Machiavelli's The Prince. He pointed out that not only people were knowledgeable about water regimes and the hydrological cycle but that the state was often supportive of such ingenious local solutions.

Archaeological evidences indicate that this so-called 'water wisdom' was unique to the development of civilizations on the Indian subcontinent. It was all a case of learning to live with nature. The first humans, who came to inhabit the Indian subcontinent, must have soon realised that water was a very ephemeral resource for them. With the monsoon season being limited to three months, people knew

that sustaining life will require extending the bounties of the wet to dry months. The diverse water harvesting systems, developed to suit some 15 different ecological regions, are the net result of human ingenuity.

## 6.11 Rural People and Water Resource Management

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### Abstract

In today's Iran villagers' participation is regarded as one of the most important topics in the development and transformation of certain rural regions. Explaining the necessities, policies and practical methods of villagers' participation in watershed management is regarded as a helpful and important solution for Iran's governmental organizations, such as the Ministry of Jahade Sazandegi. The purpose of this research is to evaluate people's participation in watershed management.

This study wanted to define people's participation in the programs related to water resources management. The conclusion reached was that watershed management combined with governmental support and peoples' participation is necessary to ensure sustainable

development and environmental protection. It is also very important to encourage rural inhabitants to participate in watershed management programs and to establish watershed cooperative associations.

## 7 WATER QUALITY

### 7.1 Assessing the Microbial Health Risks of Potable Water

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### Abstract

The health risks associated with tank rainwater consumption are not well defined. This paper provides a schematic model for considering the health impacts of rainwater with microbial contamination using the epidemiological approach but encompassing risk assessment as a central theme. The issues that need to be addressed in a microbial risk assessment (MRA) are identified. These include, for example, the numbers of pathogens in tank rainwater, their ability to survive and multiply; the extent of individual exposure; and the measurement of health outcomes. The merits of the various epidemiological study designs as tools to estimate the risk of illness from rainwater exposure are discussed. The MRA framework enables a systematic estimation of health risk as a consequence of potable tank rainwater contamination and has important implications for the setting of microbial standards for potable rainwater.

### 7.2 Comparative Review of Drinking Water Quality from Different Rain Water Harvesting Systems in Sri Lanka

**Tanuja Ariyananda**

Lanka Rain Water Harvesting Forum

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### Abstract

The main constraints on using rain water for domestic use have been the water quality aspects. The quality of rain water collected depends on the cleanliness of the atmosphere, materials used for the catchment surface, gutters and down pipe of the storage tank and the water extraction device. In the hill country and in the north central province acid rain has been recorded and in the western province rain water has carried high nitrate levels. Compared to other industrialised countries in the region, however, acid rain is still not considered a serious problem in Sri Lanka.

This study reviews the quality of rain collected throughout Sri Lanka from different types of storage tanks and roofs. It will compare the traditional rain water collecting methods with the present available technology of the Community Water Supply and Sanitation Project (CWSSP). It looks at the health aspects of drinking rain water related to biological contamination and indirectly due to disease vectors like mosquito and other insects/pest breeding in the stored water. Recommendations will be given on the different water treatment methods along with some suggestions for improvement.

The result shows that the rain water collected and stored with adequate care meets the microbiological standards set by the WHO for total coliform in drinking. The data obtained reveal that the quality of the rain water collected depends on the storage and the management of the system.

## 7.3 Contamination of Water Resources Due to the Gulf War

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### Abstract

Groundwater reserves are recharged for the most part by rain that infiltrates through the soil into the underlying layers. These reserves are occasionally augmented by streams and rivers that loose water to the underground strata. Once underground, the water flows at rates ranging from more than 10 meters a day, to as little as 1 meter a year, until it reaches an outlet. This may take the form of a spring, or of a system of slow seepage at the ground surface. It is this seepage that kept rivers flowing during dry periods.

Some 2500 years ago, the use of “Qantas” was developed in Iran. These are long, horizontal galleries, connecting aquifers at the foot of mountains to fields and villages several kilometers away. The use of Qantas spread, as far afield as Egypt, China and Afghanistan, and many such streams are still used today. Once pollutants reach the water, it, may take a very long time to flush out the aquifer completely. Furthermore, pollution can take a very long time to show itself since the water within aquifers moves so slowly.

Northern coastal regions of the Persian Gulf include major riverine systems. These are Karkheh, Karun, Maroon - Jarahi, Zohreh, Shapor-Daleki, Mand, Sahel Jonoobi, Kal, and Minab-Bandar Abbas. The total area covered by these water resources systems is 363381 km<sup>2</sup>.

Annual precipitation is about 185 mm in Kerman Province to about 250 mm in Khuzestan and greater in provinces located in the Zagros mountain ranges. Most of the rain and snow precipitates in winter and early spring. Shallower underground water resources are used for agricultural irrigation and drinking. The pollutant affects of the 1991 war of Iraq against Kuwait, on water resources, have been obvious since the measured data of acid rain and black rain (soot), showed the contamination of water resources used widely for drinking, irrigation, and industrial purposes. Once polluted, aquifers are difficult, in fact, sometimes impossible to clean up. Samples of water (both surface and underground) from Khozestan region have had contaminating compounds following the burning of Kuwait oil wells and precipitation of black rain. Since contaminated rain incidences accounted for about 30% of the

annual regional of underground water depositions (a total of  $13353 \times 10^6 \text{ m}^3$ ); i. e.  $4 \times 10^9 \text{ m}^3$  of contaminated waters.

According to the WHO report, about 4 billion cubic meter of affective rainfall has been contaminated by different hazardous materials in arid areas at the southern part of Iran. In case of using this source of water, it is necessary to clean up or dilute the water before using it for any purpose.

## 7.4 Is Rainwater Safe to Drink? A Review of Recent Findings

**John Gould**

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### Abstract

Numerous studies have shown that due to contamination following contact with the catchment surface, stored rainwater often does not meet WHO guideline standards for drinking water especially with respect to microbiological quality criteria. This does not in itself mean that rainwater is unsafe to drink. Millions of people in rural areas around the world depend on rainwater for drinking and other domestic purposes and the number of reported cases of serious health problems related to rainwater supplies are very few. In this paper, some of these rare rainwater related disease outbreaks and other potential health risks due to atmospheric pollution contaminating rainfall are reviewed. Other concerns resulting from heavy metal and chemical contamination are also examined and findings from surveys conducted in North America, Australasia and Asia are discussed. While health risks may be small, these findings suggest there is little room for complacency and every effort needs to be taken to minimize rainwater contamination. Several methods to improve the quality of water produced by any rainwater catchment system are briefly described including appropriate system design, sound operation and maintenance, first flush devices and treatment.

## 8 RAINWATER CATCHMENT SYSTEMS IN AGRICULTURE

### 8.1 Strategic Water Development in Rural Kenya - The Importance of Rainwater Catchments

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### Abstract

80% of Kenya's population is rural and agriculture based. The majority of rural Kenyans rely on small-scale (subsistence) farming. The economic importance of rainwater catchment combined with small-holder irrigation has not been properly evaluated for Kenya, hence the investigation presented in the present paper.

The investigation adopts a systematic, integrated and strategic approach (SISA) to evaluate the role of rainwater catchment in rural Kenya. The emphasis is on subsistence and appropriate technologies as well as management of natural resources (particularly land and water).

In conclusion, recommendations are presented on how proper strategies can result in promotion of rainwater catchment and utilisation for food security in the new millenium.

## 8.2 Efficient Use of Rainwater in Irrigation in Southwestern Saudi Arabia

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### Abstract

In arid and semi-arid regions of the world, where water resources are scarce, man had developed many methods of utilizing surface and groundwater as well as rainwater. Efficient methods to catch rainwater and use it for many purposes have been used throughout the Middle East for many centuries. One very-well known method of utilizing rainwater for irrigation is terracing. It is widely practiced in the Southwestern part of the Kingdom of Saudi Arabia. System of terraces used will be described. Its advantages and limitations will also be presented.

## 8.3 Rainwater Catchment Techniques in Burkina Faso: Research Status and Development Priorities

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### Abstract

Agriculture in Sahelian countries is strongly dependant on rainfall. Since the beginning of the seventies deteriorating climatic conditions have been observed in this region. This has particularly resulted in a low and /or a bad space-time repartition of rainfall. Giving that it is impossible to efficiently modify the climate, one must try to manage in the best way the entire rainfall. In Burkina Faso, several research and development institutions have been dealing with this problem since the beginning of 1973-74 Sahel drought. Unfortunately the drought still persists today. This paper summarizes what has been done in Burkina Faso regarding developing technologies for rainwater catchment. Several techniques including, flat ploughing, earthing up and tied ridging have been compared to the traditional non soil tillage in a pluri-annual and multi-local agronomic trials conducted with respect to all the eco-climatic conditions of the country. Some other rainwater catchment systems have been tried, particularly in the North of the country, to make more water available for supplemental irrigation on rain-fed crops or watering of animals.

## 8.4 Small-scale Water Management in Farming Systems in the Brazilian Arid Zones: What Is Being Done and How to Improve Its Application

**Everaldo Rocha Porto, Aderaldo de Souza Silva, José Barbosa dos Anjos, Luiza Teixeira de Lima Brito & Paulo Roberto Coelho Lopes**  
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### Abstract

The Brazilian semiarid tropics occupy an area of approximately one million square kilometers and

have about 20 million inhabitants. Most of the farmers are dependent on subsistence farming characterized by small land holdings, limited financial resources and productivity that is both unstable and low. Misuse and abuse of natural resources are causing heightened concern about the sustainability of the Brazilian semiarid tropic agriculture. Rainfall is highly variable and poor soils predominate.

The Center for Agricultural Research in the Semi-Arid Tropics (O Centro de pesquisa Agropecuária do Trópico Semi-Árido--CPATSA) was established by the Government of Brazil to seek ways to change the low quality of life endured by the residents of the Northeast. A comprehensive program to promote and improve small-scale water management in the region has been underway since 1977, and will be discussed in this article. Components under study include runoff inducement, water harvesting, recession farming, life-saving irrigation, subsurface dams and cisterns for drinking water. Significant technical achievements have resulted to date. The need to improve technology transfer has been recognized. Moreover if rain-fed agriculture in the Brazilian semiarid tropics is to have a sustainable base, a systems approach regarding social policies is a fundamental need.

## 8.5 The Assessment of Agricultural Rainwater Catchment Systems in Mudstone Areas

**S.C. Chu, T.Y. Horng, L.J. Chen, W.L. Huang, C.H. Hsu & Y.C. Huang**

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### Abstract

Ninety percent of the annual rainfall is concentrated during summer and typhoon seasons in Taiwan. Water shortage periods usually last more than six months. Irrigation water depends entirely on rainfall. Rainwater collection should be a potential alternative water source for supplementing agricultural water needs. This paper attempts to assess the feasibility of rainwater catchment at Yujiing, Tainan County, based on its location, technology, water supply and demand, economy, social and water quality. Simulation analysis is used to determine the variability of water supply reliability with the agricultural rainwater catchment system model. This may also shed some light on the feasibility of constructing agriculture rainwater catchment systems are suitable, based on all aspects considered, for use in Yujiing areas.

## 8.6 Methods of “in situ” rainwater catchment

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### Abstract

In Brazil's semiarid region, rainfall patterns are an important factor for the success of rain-fed agriculture. Erratic and uneven rainfall is the main cause of crop losses. The traditional planting system in the semiarid region is pit seeding in a level surface, using a hoe, forming a little pit capable of catching and storing a limited amount of water. Apparently, this system seems to cause no harm to the environment. However, since the soil has not been ploughed, its surface becomes slightly compacted, making infiltration more difficult and run-off easier. Therefore “in situ” rainwater catchments are more suitable to the existing planting systems and they can be implemented with the help of machines or animals. The most used “in situ” rainwater catching practices in Brazil's semiarid

region are: pre- and post-seeding furrowing, stopped furrows, W system, partial plowing and the Guimarães Duque system. The more suitable rainwater collection systems for semiarid farming conditions are presented in this paper.

## 8.7 Maintenance of Productive Soil Capacity Through “in situ” Rainwater Catchment Systems

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### Abstract

The effect of organic and chemical fertilizers applied at time were evaluated together with “in situ” rainwater catchment in zea crop. Two rainwater catchment techniques were used, one known as W and other as Guimarães Duque. Five treatments were used as follows: 1. Control (without fertilizers); 2. rainwater catchment plus manure; 3. rainwater catchment plus phosphorus; 4. rainwater catchment plus organic composite, and 5. rainwater catchment plus manure plus phosphorus. The same trend was observed in all treatments in both rainwater catchment systems. Treatment 5 showed the highest corn yield, followed decreasing by treatment 4, 3, 2 and the control. All the treatments showed higher yield in the rainwater W catchment technique than in the Guimarães Duque technique, indicating a better efficiency of the first for water storage in the soil.

## 9 RAINWATER CATCHMENT SYSTEMS IN URBAN AREAS

### 9.1 Local Governments’ Financial Assistance for Rainwater Utilization in Japan

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### Abstract

Since rainwater hasn’t been recognized as a valuable water resource in Japan it hasn’t been used to its full potential. Our main concern is the efficient rainwater collection. In the recent past people living in urban areas suffer from water shortage while occasional heavy rains cause flooding. A city's water supply usually depends on a far-away source.

One of the solutions to this problem is a rainwater utilization system using cisterns or seepage pits. These have been popularized gradually in Japan, mostly equipping public buildings. To make rainwater collection more standard individuals have to start using it as well. Therefore some local governments have established financial assistance program for people equipping their homes with rainwater collection systems.

In this paper, the existing state of financial assistance differing from one local government to the next is investigated.

## 9.2 Rainwater as a Source in an Innovative Urban Dwelling

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### Abstract

The Toronto Healthy House is a duplex dwelling in downtown Toronto, Ontario, Canada that is completely independent of municipal water and wastewater services. Water for potable use is obtained from the roof and yard surfaces, and grey water and black water are recycled for other uses. The capacity of the rainwater cistern was determined using a program developed for agencies of the Nova Scotia government. Rainwater is treated by dual filtration and ultraviolet disinfection. Monitoring results confirm that potable water quality meets Canadian Drinking Water Standards.

## 9.3 The Study for Influencing Factors of Urban Rainwater Catchment System Capacity

**S.C. Chu, C.H. Liaw, W.L. Huang, S.K. Hsu, Y.L. Tsai & J.J. Kuo**

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### Abstract

This study initially examines the different water demand, catchment area and storage capacity. The water input is simulated using several rainfall record intervals, and the Critical Period Technique. Sensitivity analysis is conducted on the variables affecting the system that include catchment area, duration of rainfall records, and water demand. The relationship between water release, storage capacity, and rooftop catchment area is established under different water demand conditions. This information would be useful and essential for the planners and decision-makers in selecting and optimizing the rainwater catchment system design.

# 10 RAINWATER RUNOFF MANAGEMENT

## 10.1 Estimation of Water Use by Vegetation Barriers Based on Climatological Factors and Soil Moisture Levels

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### Abstract

Runoff management is one of the tools to increase the available water for agricultural production in

areas where rainfall is erratic. Vegetation barriers have shown to increase the amount of water in the soil by slowing down runoff and thus allowing more time for infiltration. They do not cause upstream water logging problems due to the semi-permeable character of the barrier. However little is known about the water use of the vegetation barrier and thus whether its conservation effect is not being minimized by its own water use. This paper presents the results of a study conducted in Burkina Faso in 1996 in which a method has been developed to assess the water use of a vegetation barrier. Transpiration (sapflow) was measured on 3 barrier species (*Andropogon gayanus*, *Piliostigma reticulatum* and *Ziziphus mauritiana*). Transpiration was related to meteorological factors and soil moisture availability. The method used was found to be simple and reliable. The results can be used in other experiments focusing on the water use of (natural) vegetation and its competition with agricultural crop water use.

## 10.2 Rainfall Runoff and Sediment Reduction Effect of Hedgerow Plants on Purple Soil Slopeland

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### Abstract

Rainfall runoff and sediment reduction effect by hedgerows plants on purple soil slopeland were studied based on natural precipitation observations and simulated rainfall experiments. Measurement data revealed that hedge plants grown on 25 degrees slopeland can reduce runoff by 22-43 percent and sediment yield by 94-98 percent. These substantial decreases can be achieved at a cost of only 10-20 percent of the stone ridge horizontal terraces. Hence, it is an effective way to control runoff and soil loss in ameliorating slopeland utilization in the Three Gorges Reservoir areas of Yangtze River, China.

## 10.3 The Effect of Spatial Averaging of Rainfall on Erosion at the Catchment Scale

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### Abstract

Rate of raindrop erosion in most of physically based erosion models is a non-linear function of rainfall intensity. Owing to some practical constraints rainfall input data used in these models do not often represent the spatial and temporal variations of rainfall storms as important factors in simulation of raindrop erosion. Therefore the used rainfall input data are either spatially averaged or their spatial and temporal resolutions are not desirable for this purpose. In the present study the effect of spatial averaging of rainfall data and random selection of rainfall stations on the simulated rate of raindrop erosion in four catchments with different sizes (ranging from 1.4 to 1600 km<sup>2</sup>) using SHETRAN model were investigated. It was found that for frontal type rainfall data (generated by MTB method) the effect of spatial averaging of rainfall on simulated raindrop erosion in small catchments is much less than that in larger catchments. It was also found that the raindrop erosion can be simulated with enough accuracy where the rainfall data from at least four randomly selected rainfall stations across the catchment is used.

## 10.4 Hydrological Regularization in Alluvial Areas—A Case Study in Brazil's Semiarid Northeast

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### Abstract

The economy of the Brazilian Northeast is still based on non-irrigated agriculture. Irregular rainfall and high evaporation rates require irrigation for crop development and dramatically reduce water resources during dry periods. When rainfall occurs, rates are usually high and water is lost by runoff. Alluvial deposit infiltration rates are usually high and reduce the surface loss by refilling the underground reserves. Quantitative and qualitative investigation have been carried out in an pilot irrigation project in an alluvial area in the semi-arid region of the Brazilian Northeast. Between the dry and the rainy season, seasonal water levels and salinity concentrations have been recorded. In general, salts are leached by the beginning of the rainy season, and salt concentration increases at the groundwater. By the end of the rainy season, salts are discharged from the deposit, and water resources are available for farming.

## 10.5 A Simulation Model of Flood Runoff Utilization in Taiwan

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### Abstract

Watershed data are being gathered in Taiwan that includes soil, topography, hydrology, and land use. These information along with the AGNPS model are used to assess watershed conditions and objectively evaluate storm-related generation and transport of non-point source pollution. The main objective of this pilot study is to simulate storm water collection using retention ponds and infiltration enhancement through tree planting. Runoff volume results from various storm sizes may provide adequate information for a follow-up on-site study to optimize flood runoff utilization in Taiwan.

## 10.6 Practical Soil Science Applications for Estimating Runoff in Semiarid Regions

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### Abstract

The evaluation of watershed water flow using traditional methods is a difficult task due to the high cost and the time needed to carry out the task. This work presents a safe and practical methodology by using the calculation of the  $L_{600}$  of a watershed taking into account the hydrological characteristics of the soils of Brazil's semiarid Northeast. The  $L_{600}$  coefficient corresponds to a model water depth with runoff on a specified soil class or map unit in this semiarid region, receiving about 600 mm of rain per year. This method allows a fast evaluation of the water resources in small watersheds in areas of Brazil's Northeast averaging less than 1,000 mm precipitation/year. The method is based on the determination of the runoff after applying a standard water depth ( $L_{600}$ ) on soil classes or soil map units present in a drainage watershed. The central values proposed for the  $L_{600}$  for the main soil classes of this region were obtained under an "average" natural condition. However, the calculation of

$L_{600}$  must be corrected for the vegetation cover, ponds upstream from the measuring station and other affecting factors, such as local subsurface geology, climate and landform characteristics. Experienced soil scientists are needed to adjust the measured results. One example for these adjustments, is the one for Planossolos where the standard results of 70 mm can vary from 10 to 125 mm when the variations on the depth of the A horizon is taken into account. This reduction is aggravated in a deeper and more exposed Planossolo found in the lower part of the toposequence.

## 11 HYDROLOGY-RELATED ISSUES

### 11.1 Water As A Means of Reconciliation in the Middle East

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#### Abstract

Fresh water, the key element for life, is a critical resource in the Middle East. There is a conflict among the region's countries because of scarcity and misuse of fresh-water. Scarcity is one element of the crisis, inefficiency is another factor. In fact, water used in the agricultural sector exceeds by ten times water used in the industrial and municipal sectors combined. There has been a rapid population growth in the Middle East in recent decades. This population boom has put an extreme pressure on the existing limited and vulnerable water resources.

An integrated management of water resources including technical, social and economic aspects is needed, since, unlike oil, water cannot be easily exported from a water-surplus country to a water-deficit country due to economic, political, environmental, psychological, ideological and emotional reasons.

One of the most important aspects of land and water resource development programs is to determine the inventory of the resources. The resources and opportunities should be known accurately, and current supplies and future supplies which will be available as a result of supply management policies in terms of foreseeable water demands should be considered. However, in the Middle East there is no scientific co-operation on the crucial importance of demand management aiming at water use efficiency, equity, and long-term water security. If nations of the region would share both water technology and boundary resources, fresh-water could not drive them to war, and it will not be a hindrance for peace.

In 1988, Turkey proposed a "peace pipeline" of water from two Turkish rivers- the Ceyhan and Seyhan- that flow south into the Mediterranean sea. The dual pipelines would deliver potable water to millions in Syria, Jordan, Saudi Arabia and other Arab gulf states.

### 11.2 Eastern Anatolia Watershed Rehabilitation Project

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#### Abstract

Turkey is one of the countries severely subjected to erosion. It is estimated that over 600 million tons of soil per year are lost to the seas and lakes by erosion.

The Eastern Anatolia Watershed Rehabilitation Project has been developed as a result of an agreement

between the World Bank and the government of Turkey signed in 1993 with the objective of conservation and development of vegetative structure and water resources, prevention of erosion, rehabilitation of rangeland and improvement of living conditions of the villagers over the middle basin of the Euphrates River. In Elazig, Malatya, and Adiyaman provinces 54 micro-catchments will be used as experimental sites over the next six years.

From the environmental point of view, the purpose of the project is to achieve sustainable protection and development of the soil and water resources. From the socioeconomic view point, the purpose is to involve the local communities in the project activities, thus increasing rural income by developing various income generating activities.

## 12 POSTERS

### 12.1 The Use of Moringa Trees

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#### Abstract

Different countries in Asia, Africa and Latin America have a tradition of using various plants as coagulants or natural flocculants. The goal of this process is to speed up the colloids in the water destined for human consumption. Due mainly to the presence of clay particles and organic matter, these waters don't fulfill the qualitative criteria for human consumption, as much from the physical point of view (high turbidity) as well as from the microbiological contamination. The Moringa family, and in particular *M. oleifera* and *M. stenopetala*, are among the most promising natural coagulants. Besides having this coagulating quality in their seeds, these medium-size trees can be useful in other ways (pharmaceutical, nutrition, natural sweetener) for the people in the numerous tropical countries where they grow.

### 12.2 Pintadas: Experiences with Concrete Plate Cisterns

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#### Abstract

Pintadas is a small county in the semiarid region in the central part of the Sertão Baiano (the interior of the State of Bahia), covering 530 km<sup>2</sup>, with 10,500 inhabitants, 78% of whom live in rural areas. Water has always been scarce and of bad quality. Because of its scarcity, water is a source for political dominance, particularly in the rural zone. This concern led the CCSP (Centro Comunitário e Social de Pintadas—Pintadas Community Center) to develop an infrastructure for water storage.

The concrete plate cistern was invented about 35 years ago by Nel, a mason from Simão Dias, Sergipe. Building pools in São Paulo, he had learnt to use prefabricated cement plates. He returned to the Northeast and used his experience to create a new type of rural cistern. It is shaped like a cylinder, made of round pre-fabricated plates and called plate cistern.

Based on Nel's invention, the CCSP started training masons in Pintadas. Equipped with this skill, the costs and time to build cisterns were cut down. Today one needs only 3 working days and R\$ 430,00 (US \$260) to build a cistern with a 15,000 l capacity. So far we have built 650 concrete plate cisterns. A great advantage for the population who is now drinking cistern water rather than water from water

holes, thus reducing the risk of diseases. People who used to walk a long distance to fetch water have now more time for other activities.

This is how Pintadas became known as pioneer in the building of concrete plate cisterns. Even though Pintadas didn't invent this cistern, it was here that this technique was first applied and it spread from here. Nowadays we are receiving many visits and we are training people and organizations all over the Northeast.

### **12.3 Construction of Wire Mesh Concrete Cistern in the Xixiaklhá Community of the Indigenous Fulni-ô, Águas Belas - Pernambuco**

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#### **Abstract**

The Fulni-ô people are the last remaining of the indigenous people in the state of Pernambuco. They live in the county of Águas Belas, in the semiarid region, about 310 km from the state capital Recife. Until today, the 11,500 ha of lands promised to the Indians in 1877 by the provincial government have not been handed over. Currently there are about 4,000 Fulni-ô. They are divided among those living in the main aldeia (indigenous village) Fulni-ô, the small aldeia Xixiaklhá and those who try their luck in other cities and states.

Among the Fulni-ô, the Xixiaklhá, consisting of 14 families, are the poorest. This community is the one suffering the most from the lack of water. They are far from the city and they have no water supply system. The people have been consuming the water from the creeks, which carry the sewage from the city.

Various institutions had been trying to establish activities necessary for survival, such as a community garden or the construction of a cistern holding 4,000 liters of water. But it has been in vain. Because of the crystalline subsoil the construction of a well made with a pile-rammer (CHECK) did not work either. After various discussions between CIMI (Conselho Indigenista Missionário—Missionary Indigenous Council), IRPAA (Instituto Regional da Pequena Agropecuária Apropriada—Regional Institute for Appropriate Agriculture), Polo Sindical (Trade Union Umbrella Organization) of Petrolândia and the indigenous community, it was decided to build wire mesh concrete cisterns as the best solution to provide drinking water for the people.

With the construction of 14 cisterns for all the houses in the Xixiaklhá community, CIMI is aware that not all problems were solved, but at least it's a point of departure to provide the Fulni-ô and other indigenous people of the semiarid Northeast with the means of living with the semiarid climate and to strengthen their culture and autonomy.

### **12.4 Nitrogen Transport Through the Vadose Zone of the Bisheh Zard Aquifer**

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#### **Abstract**

The critical water shortage, an abundance of floodwaters and the very large empty spaces available in the potential aquifers have made artificial recharge of groundwater (ARG) the method of choice for

storage and transport of the required water in the Iranian deserts. The Bisheh Zard Aquifer, with the capacity of more than  $100 \times 10^6 \text{ m}^3$ , provides an ideal underground reservoir that could supply water to 4 villages for 5 years if fully recharged. However, the presence of geologic-N in the watershed is a cause for concern. Although the inhabitants of the Gareh Bygone Plain (GBP), who consume the water that drains from the watershed do not report any ill effects. The reported cases of digestive track cancer and the blue baby syndrome in the USA make us apprehensive for the water users' safety. As palygorskite translocation to a depth of 7.5 m has been ascertained in a previous study and the reported anion exchange capacity of this clay species is considerable, therefore, the N pollution of the aquifer and groundwater in the ARG systems of the GBP is a possibility. The relationships between the clay translocation and the contamination of the aquifer will be discussed.

## 12.5 Geologic Nitrogen in the Agha Jari Formation of the Bisheh Zard Basin: A Dilemma

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### Abstract

Nitrogen deficiency ranks right behind water as the second most constraint to crop production in the coarse - loamy sand of the Gareh Bygone Plain (GBP) in southern Iran. As better resource utilization is essential to wise energy management, contrary to the reported cases, surface water pollution by N maybe a boon in the GBP. The Agha Jari Formation, in which the Bisheh Zard Basin (BZB) that supplies the GBP with floodwater has been formed, contains  $\text{NO}_3$  and  $\text{NH}_4$  in its sandstone, siltstone and marl components. Therefore, it is expected that some of the geologic N dissolved in floodwater, and carried by the suspended load, reach the watertable, and also supply the plants coming in contact with the water and/or sediment.

To study the origin of N in the BZB, and investigate the fate of the dissolved and adsorbed N as it travels from the watershed to the watertable, 13 rock samples, 7 floodwater samples and 71 soil samples were collected and analyzed for  $\text{NO}_3$  and  $\text{NH}_4$ . The  $\text{NO}_3$  concentration was higher than that of  $\text{NH}_4$  in all of the samples: 77 ppm vs. 38 ppm in the floodwater; 47 ppm vs. 20 ppm in the soil; and 22 ppm vs. 12 ppm in the rocks. Assuming the mean annual inflow of the GBP floodwater spreading system in 10 million  $\text{m}^3$ , the system receives 370 metric tons of  $\text{NH}_4$  and 770 metric tons of  $\text{NO}_3$  which exceed the N requirement of the small grains if this system is planted to them.

As the U.S. Environmental Protection Agency has declared the maximum contaminant level of  $\text{NO}_3$  - N at 10mg per liter (44.4 mg  $\text{NO}_3$  per liter), and its concentration in floodwater in the GBP is 1.73 fold that amount, purification of the water is in order. High  $\text{NO}_3$  consuming plant species might offer an environmentally friendly technology to decrease the deleterious effects of N containing floodwater. The study concerned with the flow of N towards groundwater will be reported later.

## 12.6 Optimization Analysis for Utilization of Rainwater in the Lake Land Plain

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### Abstract

The utilization of rainwater is an essential measure taken to overcome the crisis of water resources in dry areas. This paper examines how to fully utilize stream-flow water and reduce the need for water

pumping by using a simulation and system analysis approach. The Weishan Lake-Luoma Lake water resources system's pump-storage probability curves have been obtained, based on historical and generated stream-flow series data. The system response values of each operating alternative have also been calculated and the Pareto-solution generated. The optimum solution can be determined based on the priority of system objective importance and considering the local economic base and the national economic developing demand.

## 12.7 Artificial Recharge System and the Fate of Dissolved and Suspended Particles in Floodwater: A Case Study in Damghan Playa, Iran

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### Abstract

Spreading floodwater on arid lands is a new widespread experimental technique that is in progress in several parts of Iran. Intensive short period rainfalls, characteristic of arid regions, carry huge amounts of soil particles of various sizes. Damghan playa, where an artificial recharge project is in progress, was selected in order to study the fate of carried suspended and dissolved particles of clay, calcium carbonate, and gypsum. This playa is located 30 km east of Damghan city. The main objective of this investigation was to determine the effects of artificial recharge system on transportation of soil particles and their subsequent redeposition in soils. Calcareous and gypsiferous parent materials of the region were found to be the source of clay, calcium carbonate, and gypsum particles carried by floodwater. Physico-chemical properties and micromorphological characteristics of soils were determined in order to study distribution and redeposition of these particles in soil profiles. Results of this investigation showed some physico-chemical and micromorphological changes in soils. Changes included translocation in addition to calcium carbonate, gypsum, and clay particles; type and distribution of voids; reduction in soil permeability; formation of cutans and calcitans; calcite hypocoatings; and calcite infillings of voids. Deposited particles caused plugging of large voids.

## 12.8 Poços Bate-estaca: Brazilian-Style Tube Wells

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### Abstract

Tube wells present a simple well sinking method. A boring iron pipe with a steel plate on a lever sitting on frame is pushed up and down by a few people, opening the well. The use of water in this operation, makes opening the hole easier. In order to take out the soil, the boring pipe is taken out and another similar iron pipe equipped with a valve is inserted to take out the loosened soil. The boring holes have to be covered to avoid the surrounding earth from closing the hole. This technique can be applied in sandstone areas, but not in granite. Tube wells can be sunk to a depth of 90m.

Once the well is opened, one can use suction pumps or a pipe with an valve attached to a cord with a pulley, which will be pulled out after filling up. Local workers have carried out these well sinking task and their participation has helped many communities. Tube wells have been a solution not only for the water scarcity but also for lasting sustainable development, improving the quality of life, combining economic efficiency (the wells are cheap) and social justice, without harming the environment. A negative aspect is the duration of the boring, but it is compensated with the cheap costs and a simple technology accessible to all workers.

## 12.9 Who drinks what: Potable Water Usage in South Australia

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### Abstract

Recent studies which have implicated mains supply water as a source of gastroenteritis (Paymentet al, 1991; 1997), have ramifications for water supplies in Australia. This is particularly so for those water supplies in rural or semi-rural communities where the source water is often of a lower quality and its treatment limited.

Rainwater collected and stored in tanks on domestic premises is an important source of potable water in South Australia. However knowledge about the risk to health from drinking tank rainwater is limited. Potential sources of contamination include faecal material from birds, rodents, possums and other animals; accumulated fallout from air pollutants; breakdown products from roofing material, and organic debris from overhanging trees. The focus of this study is the microbiological quality. A number studies of tank rainwater have indicated the water quality to be below guideline values for indicator organisms (Fuller et al. 1981; Thomas and Greene 1993; Edwards 1994). Cryptosporidium and Giardia cysts have been detected in tank rainwater in the Virgin Islands (Crabtree et al, 1996). Tank rainwater has also been implicated as a cause of an outbreak of gastroenteritis in Trinidad (Koplan et al 1978).

## 12.10 Big Basket Dam (Gabiões Dam)

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### Abstract

The Barragem de Gabiões (Big Basket Dam) is a technology that has been used in the counties of Oeiras and São João da Varjota in the state of Piauí, by the parish of Oeiras as well as the CEFAS (Centro Educacional São Francisco de Assis--San Francis of Assis Educational Center).

The Big Basket Dam is made of a stone wall held together with the help of cage wires (basket) and grounded with cement wall in the middle. It's a technology used to keep creek and small river water, taking advantage of rainwater and runoff spring water.

It is necessary to make sure that one chooses the right place to build the dam. The proper choice influences the success of the construction and its total cost. The secret is to find a place that's steady in the riverbed as well as on its banks.

Advantages:

- Utilization of regional materials (stones), little use of bought materials (cage wire and cement)
- Easy construction
- No requirement for skilled labor
- Needs lots of workers, gives value to the work within the region.

Disadvantages:

- Difficulties in locating the right site
- Cannot be applied everywhere (the rives has to have stones and solid rocks)
- Needs lots of workers
- One dam alone isn't very effective
- A series of dams within the same river or creek will bring much better results.

## 12.11 A First Flush Device for Rainwater Collected and Stored in Rural Cisterns

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### Abstract

In order to improve the quality of rainwater collected from roofs of rural buildings and storage in cisterns, a system composed of a collector tank, a siphon (T of PVC), a buoy and tubes was developed. The objective was to eliminate some of the impurities contained in the reception area.

The water collected from the first 4 millimeters of each rainfall, is deviated through a “by pass” together with the impurities and diverted into a collector tank, thus transporting all possible pollution and polluting agents.

## 12.12 Results of Underground Temperature Surveys: Detecting the Groundwater Vein-Stream at the Barikan Landslide Area in Iran

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### Abstract

It is known that underground water does not form a groundwater surface but forms a groundwater vein-stream at the head scarp after the occurrence of landslide. Generally, landslides are caused by the influence of underground water (pore pressure on the sliding surface) in the mass. Therefore as a countermeasure to landslides it is necessary to drain the groundwater.

When the groundwater temperature is measured at the spring-water points and bore holes in the landslide area, we see that the annual variation of temperature is comparatively stable. On the other hand, we see that the annual variation is not stable near/on the ground surface. Based on these phenomena, Takeuchi (1980, 1981) has developed a method of investigating groundwater vein-streams by measuring the temperature at a one-meter depth. This method provides the basic information for countermeasure for drainage of underground water at landslide area in Japan (e.g., Takeuchi, 1981). The purpose of this paper is to detect the Plain distribution of the groundwater vein-stream at the Barikan landslide in Iran with the help of the underground temperature survey and to examine if this vein-stream can be a useful water resource.

## 12.13 Underground Temperature Survey for Detecting the Groundwater Vein-Stream

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### Abstract

It is known that rainwater infiltrating into soil tends to drop infiltrating velocity to the vertical direction and tends to flow horizontally when it reaches an unpermeable layer. Therefore it is

necessary to determine exactly the location and depth of the groundwater vein stream flowing above the unpermeable layer for effectively using groundwater.

In order to accomplish this, an electric resistivity survey and an electric logging have been carried out. The information on the location of the groundwater is obtained by these methods. It is very difficult though to obtain information on the location and depth of flowing groundwater in vein streams.

The authors developed an underground temperature survey method to detect the accurate information on groundwater vein stream. This method uses the difference between temperature of flowing groundwater and ground temperature of a shallow layer. It is composed of a one-meter- depth temperature survey, a multiple point's temperature logging and/or usual temperature logging, and a flowing direction and a velocity measurement.

The groundwater investigation method utilizing temperature is extensively used for research of groundwater vein-streams in landslide areas, underflows, groundwater disasters, groundwater obstructions and groundwater resources.

## 12.14 The Effect of the Storage Location on Collected Rainwater Quality

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### Abstract

Water quality in stored rainwater changes during storage for various reasons and it is necessary to investigate these variations in order to use it safely. In this paper, an attempt is made to examine the effect of the location of storage reservoirs on rainwater quality. However, the experiment was carried out using groundwater instead of rainwater due to a lack of rainfall during the period of the experiment. Water that was stored in the containers located both indoors and outdoors was analyzed for ammonia nitrogen, nitrite nitrogen, nitrate nitrogen, turbidity, color, coliform bacteria and bacteria periodically for about three months from the beginning of August to the end of October. The results obtained show that variations in water quality were insignificant between the water stored indoors and outdoors, but the appearance of water was quite different.

## 12.15 Minimum Cultivation with “in situ” Rainwater Catchment Systems

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### Abstract

Crop residues management effects associated with rainwater catchment practices were evaluated in a rain-fed maize cropping. The Guimarães Duque rainwater catchment system was used. Five treatments were carried out with the following arrangements: T1 Control (catchment system, without annual recovery, removing crop residues from soil surface after harvesting; T2 Catchment system with annual recovery, removing crop residues from soil surface; T3 Catchment system with annual recovery, incorporating crop residues with the sowing line; T4 Catchment system with annual recovery, planting black mucuna as green manure, incorporated in the sowing line together with crop residues; T5 Catchment system without annual recovery, planting black mucuna as green manure, but leaving crop residues on the soil surface. The treatments leaving crop residues as mulching or

incorporating them in the sowing line (T5, T4, and T3) showed higher yields, but they did not statistically differ from each other. However, they significantly differed from those where crop residues were removed from the soil surface after harvesting (T1 and T2).

## 12.16 Rain Water Catchment System of Mizoram State, India

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### Abstract

The state of Mizoram, located in the extreme northeast corner of India, is a small hill state having an area of about 21,000 km<sup>2</sup> and thinly populated. The state is entirely mountainous covered with green vegetation. Villages are mostly located on hilltops. Mizoram State enjoys abundant monsoon rainfall of about 2500 millimetres annually. But Run-off is quick and people face acute water problems in the dry season. Villagers have to walk long distances to fetch water from perennial springs and rivers. The English who came to the area in 1894, got their domestic water from a 12- lakh gallons capacity underground rainwater tank.

Nowadays rooftop rainwater harvesting and spring water collection are the main sources of domestic water supply in Mizoram. With the development of the gravity pipe the government started supplying water with a pumping scheme. Pipe water supply is supplemented by rainwater harvesting in most of the towns and villages. Many families prefer rainwater for direct consumption to pipe water.

The Government of India and the state government have taken up rainwater harvesting from roofs as well as spring water improvement as one of the important development schemes. During the International Water Decade substantial funds for rainwater collection were released on a state as well as federal level.

## 12.17 Use of the Technologies of Collection of Runoff Water in the Semi-Arid Region of the Brazilian Northeast

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### Abstract

The scarcity of water resources throughout the semiarid region of Brazil's Northeast make it nearly impossible to either produce surplus crops or to keep a livestock of cattle, goats and sheep, usually the main source of income as well as savings of small farmers. To live in this region requires that farmers, particularly those living in dry areas, use some alternative technologies, mainly the catchment and storing of rainwater. Researching the application of these alternative technologies, we discovered that few farmers use any rainwater catchment technology.

The objective of this study was to evaluate the rainwater catchment and storage technologies of small farmers in five counties in the semiarid region. Our research was carried out between 1996 and 1998 in the counties of Simplicio Mendes (Piauí), Morada Nova (Ceará), Angicos (Rio Grande do Norte), Jeremoabo (Bahia) and Inaja (Pernambuco). In each county a random sample group of farmers was asked to answer a questionnaire.

A total of 179 farmers were asked if they use: 1) cisterns, 2) clay pits for supplement irrigation, 3) underground storage dams, 4) their own rainwater catchment systems and 5) reasons for not using any technologies.

The results obtained show that only 9,5% of the farmers use cisterns. And that 51,96% of the farmers not using them would have enough money to install them. No other technologies were used by any of the farmers. These results show the necessity for spreading the knowledge of these technologies among small farmers.

## 12.18 Superficial Runoff Induction in Microcatchments in the Brazilian Semiarid

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### Abstract

In this paper the results of a ten-year study on superficial hydrology are presented. It describes eight hydrographic micro-catchments with different natural vegetation's (caatinga) management systems in the Brazilian semiarid region, dealing with induced superficial runoff, catchment and storage of rainwater for small irrigation projects. Eight experimental micro-catchments were built in an unvaried area with the objective of evaluating several hydrological combinations of natural vegetation and soil management for induction of superficial runoff of rainwater and conservation of the natural vegetation. The experiment was carried out in micro-catchments (plots) with areas varying from 1.1 to 2.7 hectares and slopes from 0.7 to 1.4%. At the lowest spot of the plot (water exit of the superficial runoff), a Parshall gutter and a limigraph to measure flow-out were installed. In each plot a pluviometer was installed to measure the exact amount of rainfall in the area. During the duration of the study, in the one plot that had been totally deforested and where watercourse terraces had been built, the efficiency of superficial water runoff and soil losses were the highest. Followed by the plot deforested in alternate strips (50% of the original vegetation was taken out), with intense drainage and NaCl application in the deforested strips (300 g m<sup>-2</sup>) and the plot deforested in alternate stripes and building terraces in those places as a base. There was no superficial water runoff in the plot where the natural vegetation was kept without alteration.

## 12.19 Artificial Recharge Methods of Kariz

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### Abstract

Kariz is one of the Iranian traditional water harvesting systems. Unfortunately some experts believe that water loss during winter and out of the crop season is the main disadvantage of this method. One of the methods to increase the discharge of kariz, is to recharge the aquifer artificially, where the karez tunnels are dug in them. This can be done by different methods, which are divided by "surface recharge" method and "underground recharge" method. Some case studies of Iran will be considered in this paper.

## 12.20 PVC Hand Pumps

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### Abstract

The CPT (Comissão Pastoral da Terra de Caitité-- Church Commission of Caitité) offers farm workers (with manual skills) courses in building PVC-pumps.

The PVC used is rigid, welded together and has a diameter of 160 and 110 mm. This material is excellent to make hand pumps for the following reasons:

It is easy availability in the markets;

Durability;

Pressure resistance;

Easy modeling at a low temperature;

No need for sophisticated equipment;

Besides PVC tubes, one only needs wood, leather, screws and glue.

Since they have participated in these courses, farm workers in some counties are now building these pumps for their own use or to sell.

The results of using the pumps are satisfactory. When used on the ground, the pumps are capable of pumping 3,200 liters/hour. From a height of about 8 m the pumping capacity drops to 1,500 liters/hour. The maximum sucking limit is up to 6 meters, and we already succeeded in pumping water for about 300 m. The PVC- hand pump is used to take water from cisterns and holes and to pump water from wells into other containers to be used in the house as well as for animals, or to water small garden areas. In our region 100 pumps are currently in use. Their use is limited due to the limited financial resources of farm workers, after all a PVC pump costs between R\$ 90 to R\$ 100 (US\$ 54 to 60).

## 12.21 Rainwater Catchment: An Educational Program

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### Abstract

The EFA (Escola Família Agrícola--Rural Family School) in its courses on life with the semiarid region for the students of APAEB (Associação dos Pequenos Agricultores do Município de Valente - BA-- Small Farmers' Association of Valente, Bahia County), is also teaching rainwater catchment and storage.

The school has 5 cisterns (of bricks and cement) with a capacity of 40.000 liters, and another one with a capacity of 25.000 liters. All these cisterns collect water from the school's buildings. We also have a small dam that can store about 9,000, 000 liters and two water holes with a total holding capacity of 500,000 liters. Besides this, the school has 2 tubular wells with salty water with a small flow of 1200 and 1300 liters.

Given that consumption is high, it is necessary to manage the available water:

Cistern water is only used for drinking and cooking.

The dam water is used for watering plants, rainworm farm and the garden as well as for taking baths and cleaning the kitchen.

The salty well water is used for flushing toilets, cleaning the stables, filling the fish tanks and for the

animals. In one of the wells a solar desalinator was installed and it supplies 500 liters of drinking water a day.

The cisterns supply enough drinking and cooking water for the school's students. The desalinator supplies drinking water for other events such as meetings or courses held by APAEB.

Based on the program established by the school, 250 families (that is 80% of the APAEB associates) are already using rainwater from cisterns.