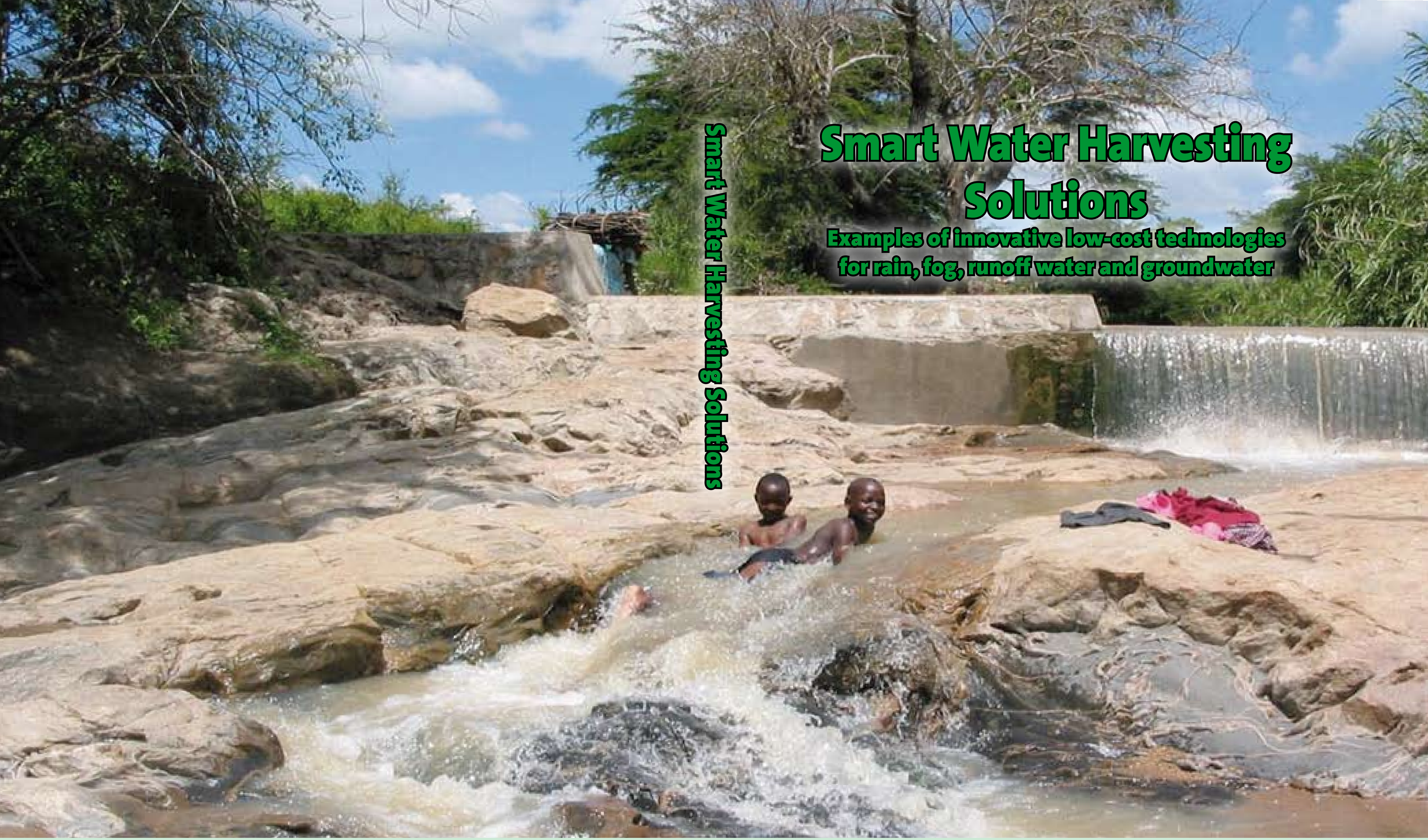

Smart Water Harvesting Solutions

Examples of innovative low-cost technologies for rain, fog, runoff water and groundwater

Smart Water Harvesting Solutions

AGROMISA

aqua for all

PARTNERS VOOR WATER
Bundeling van krachten

NWP Netherlands Water Partnership

Smart Water Harvesting Solutions

Examples of innovative, low-cost technologies for rain, fog, runoff water and groundwater

The first edition of this booklet was prepared as a contribution to the World Water Week in Stockholm, Sweden in August 2007 as result of a successful co-operation between the Netherlands Water Partnership, Aqua for All, Agromisa and all indicated organisations. Partners for Water financially supported this edition.

Collaboration

In response to increasing interest in water harvesting and the success of earlier Smart Solutions booklets on water and sanitation, this edition shares information on water harvesting technologies. It is designed as a source of inspiration, rather than a technical manual.

This publication is the result of a collaborative effort by a number of organisations:

NWP, the Netherlands Water Partnership, is an independent organisation formed by government bodies, NGOs, research institutes and businesses involved in the water sector. The main aim of the NWP is to harmonise initiatives of the Dutch water sector and to promote Dutch water expertise worldwide. *www.nwp.nl*

Aqua for All (A4A) aims to create a link between the Dutch public and private water sector and actors in water and sanitation projects in developing countries. A4A sponsors socially responsible entrepreneurship by acting as a 'broker' between all parties involved. A4A aims to tackle the scarcity of drinking water and sanitary facilities in developing countries in a structural way. *www.aquaforall.nl*

Agromisa is linked to Wageningen University and Research Centre and specialises in exchanging knowledge information on small-scale sustainable agriculture and related topics. Agromisa's main objective is to strengthen the self-reliance of the deprived population in rural areas by sharing experience and knowledge. *www.agromisa.org*

This booklet is funded by **Partners for Water**, a programme that aims to strengthen the international position of the Dutch water sector by uniting forces (companies, departments, NGOs and knowledge institutes). Partners for Water is overseen by the Dutch Agency for International Business and Cooperation (EVD) in collaboration with the Netherlands Water Partnership (NWP). *www.partnersforwater.nl*

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Table of contents

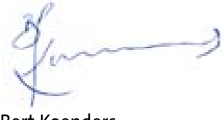
Since the Millennium Development Summit in 2000, when 189 heads of state declared their full commitment to achieve eight Millennium Development Goals (MDGs), the world has had an unprecedented opportunity to improve the living conditions of billions of people in rural and urban areas. MDG 7 -to ensure environmental sustainability- is fundamental to achieve each of the other MDGs and in particular to improve health and eradicate poverty and hunger. Target 10 of MDG 7 is to halve the number of people without sustainable access to safe drinking water and improved sanitation by 2015. The Netherlands has pledged to provide access to both safe drinking water and basic sanitation for fifty million people by 2015.

This booklet describes a number of creative solutions in situations where ‘there seems to be no water’. It shows practical efforts to ‘create water’, especially in drought prone areas. It does not limit itself to the act of harvesting, but includes ‘capturing’ water during periods of rain, so that it is available for periods of drought.

Many of the technologies highlighted in this booklet are traditional, but neglected in the modern world, as people try to become less dependent on the wiles of nature. There is an increasing awareness that rather than fighting against nature, people should co-operate with it. That is what water harvesting tries to do.

The examples illustrate how the ‘revival’ and promotion of small-scale technologies can contribute to the provision of drinking water, the development of agriculture and other income-generating activities in drought-prone areas. Water conservation and water harvesting techniques provide a key to development and as such contribute to the achievement of the Millennium Development Goals.

This booklet on Smart Water Harvesting, like its equivalents on Smart Water and Smart Sanitation, gives examples that have proven to be effective and affordable. I hope that this booklet will find its way to many local communities, civil engineers, NGOs, research institutes, donors and governments, who will use it as an effective source of inspiration.



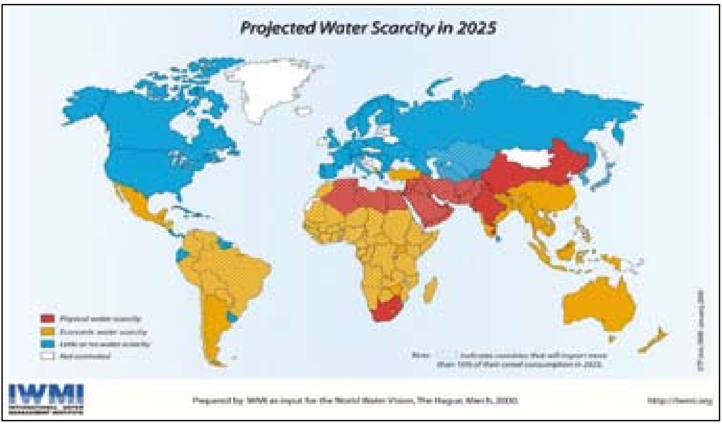
Bert Koenders
Minister for Development Co-operation
The Netherlands

The need for water harvesting techniques

Water harvesting can best be described as all activities to collect available water resources, temporarily storing excess water for use when required, especially in periods of drought or when no perennial resources are available. The starting point is the collection of natural water resources from rainwater, fog, runoff water, groundwater or even waste water, which otherwise would have escaped.

World water resources are facing dramatic changes as a result of global climate change, high water demands, population growth, industrialisation and urbanisation. As climate change leads to more extreme variations, water harvesting solutions must cope with both extreme rainfall and extreme droughts. Extreme rainfall requires good flood protection and diversion structures. Extreme drought requires large storage capacity and more emphasis on groundwater replenishment. In some cases, droughts last so long that alternative water sources are required, which means that water rationalisation schemes must be developed in advance.

The 2006 'United Nations Water Development Report' points out that a combination of lower precipitation and higher evaporation in many regions reduces water levels in rivers, lakes and groundwater. In addition, increased pollution damages ecosystems as well as the health, lives and livelihoods of those without access to adequate, safe drinking water and basic sanitation. The same report highlights how equal right of access to good quality water resources is a key challenge, crucial for domestic, agricultural, industrial and environmental use. By managing available water resources, livelihoods and human development can improve.



Source: IWMI, 2000

To respond to water scarcity and unequal distribution, new techniques need to be explored and old techniques revisited. Small-scale water harvesting techniques provide a direct solution, especially in rural and drought-prone areas.

Local storage of water is increasingly important for ensuring water availability and food security for rural and urban populations, especially in developing countries. This is particularly the case in areas with dry seasons where perennial rivers and fresh groundwater are not available or difficult to reach.

In urban areas dam construction, long distance conveyance of water or desalinisation may provide options for ensuring water availability. However, such solutions are generally too costly and complicated for rural water security. Rural populations require low-cost systems that can be constructed, operated and maintained with a high degree of community involvement and autonomy. Water harvesting may reduce the need for deep well drilling or other costly investments in piped water supplies. Water harvesting can also have a positive impact on soil conservation, erosion prevention, groundwater replenishment and the restoration of ecosystems.

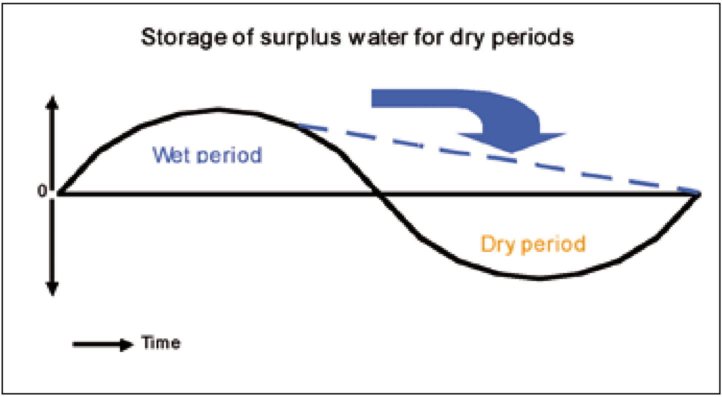
Despite its tremendous potential, water harvesting has not received adequate recognition from policy makers and engineers. Water harvesting techniques are often considered unsophisticated or 'traditional', while water quality is not always guaranteed and unit costs can be high compared to supplies in humid countries. Moreover, these techniques require a high degree of flexibility and adaptation to the local situation. Many NGOs lack the capacity or interest to upscale and institutionalise successful local innovations, and this can contribute to lack of recognition by policy makers.

Most good practices applied by small-scale farmers or development workers are developed by themselves through trial and error, by building on indigenous knowledge, or have resulted from the modified application of ideas introduced from outside. Often, these local innovations go unnoticed. This booklet gives an insight into small-scale water harvesting techniques all over the world. Some may form a good basis for larger scale application.

Facts and figures:
Projections for 2025 indicate that the number of people living in water-stressed countries will increase six-fold to 3 billion. Today, 470 million people live in regions where severe shortages exist.
1.1 billion people in the world do not have access to safe water: roughly one-sixth of the world's population.
The average distance that women in Africa and Asia walk to collect water is 6 km, carrying an average of 20 kg on their heads.
An estimated 25% of people in developing country cities use water vendors, purchasing water at significantly higher prices than for piped water.
The population in the Kibeira slum in Nairobi, Kenya, pays up to five times the price that an average American citizen pays for a litre of water.
Approximately 75% of the poor depend on rain-fed agriculture for their livelihoods. In sub-Saharan Africa the proportion is over 90% of the population, generating 30-40% of GDP.
In semi-arid regions such as sub-Saharan Africa and parts of Asia, each kilogram of grain produced requires 5,000 litres of rainfall.
The untapped potential of rain-fed systems is approximately the equivalent of doubling yields.
60% of rainfall does not end up in rivers or aquifers, but is retained in the soil, available as 'green water' for plant-ecosystems.
In typical dry land without adequate vegetation cover and degraded forest and grassland, 90% of precipitation will run off or evaporate, and only 10% will be retained.
The costs of water harvesting technologies vary from less than US$ 150 to US$ 6,500 per hectare. Small to medium-sized surface reservoirs in Africa cost between US$ 0.8 and US$ 3.0 per stored m^3, including water lost by seepage and evaporation. Subsurface dams in East Africa cost between US$ 2.5 and US$ 4 per stored m^3 of water.

The main principle of water harvesting is to work with nature, and make optimum use of available water resources, storage means and harvesting technologies.

The essence and success of water harvesting is to collect water during the (short) wet periods and to store and use it for subsequent dry periods. To achieve this, it is important to understand the water cycle, the natural purification of water and water conservation.



The development and selection of a water harvesting technique should consider all available water sources and options for collection, storage, treatment and use, and should take into account the availability of local materials and equipment. The best choice will also take into account socio-cultural, political, legal, environmental, economic, organisational and management aspects.

Available water sources

Water harvesting techniques can be categorised into four groups, according to the available water source and the storage medium:

Rainwater or fog harvesting collects water directly where it falls as rain or snow, from ground surfaces or rooftops or by intercepting fog. Rooftop rainwater and intercepted fog are commonly of a good quality, but may be affected by air pollution, dirt on roofs or rust on metal sheets. If measures are taken to prevent the first polluted flush entering storage tanks, water can be fit for drinking and other domestic use with little or no treatment.

Rainwater and fog harvesting are especially important in semi-arid areas, where it is necessary to store the maximum amount of water during the wet season for later use. Rainwater harvesting and fog interception systems generally have three common components:

A **catchment surface** for rainfall or fog interception. For collecting rainfall from rooftops, a clean impervious roof made from non-toxic materials (e.g. galvanised iron, cement or tin, without asbestos or lead) is essential. Water from thatched roofs should be filtered or treated before being used for drinking.

A **delivery system** between collection and storage. For roofs, this usually consists of gutters from the sides of the roof sloping towards a downpipe and the tank. Metal and PVC are commonly used. Splashguards prevent overshooting of rainwater in regions with high intensity rain. The runoff from the first rainfall, which contains most of the dust and debris that have accumulated on the roof, is diverted from water storage by a manually or semi-automatically operated first-flush device.

Catchment surface for fog interception, Nepal (photo: Simavi).

A **storage reservoir**. This usually involves the highest investment cost, but is generally cheap in operation and maintenance. Materials used include ferro-cement, mortar, reinforced concrete cement, rubble stone blocks, plastic and fibreglass. Round tanks are generally stronger and require less material. Tanks may be constructed above or below the ground, although underground tanks should not be constructed in unstable soils or flood-prone areas. Size can vary between 1,000 and 100,000 litres. Evaporation losses and pollution can be reduced by covering the tanks or reservoirs. Regular monitoring of the water quality, and inspection and cleaning of the reservoirs are essential for success and should be carried out by local communities or families themselves.

Family in front of a ferro-cement storage reservoir, Burkina Faso (photo: RAIN foundation).

An appropriate tank size can be selected, based on an estimate of seasonal rainfall or fog patterns, catchment or interception surface, length of dry period and per capita demand for safe water. One can install a small household system or a bigger community level system.

Rain and fog harvesting are good alternatives for domestic use when centralised systems are not available or affordable. Local ownership is important for sustainability. In multipurpose systems, sufficient water needs to be safe for domestic use at the end of an exceptionally dry period.

Rainwater delivery system, Burkina Faso (photo: RAIN Foundation).

Surface water harvesting includes all systems that collect and conserve surface runoff after a rainstorm or in (intermittent) streams, rivers or wetlands for storage in open ponds or reservoirs. This usually provides water for irrigation, livestock and aquaculture. For domestic use, treatment is generally required.
Water in rivers or streams can be directly collected through a 'Tyrolean weir' or using the finger pond system, or indirectly by diverting it to ponds and / or spreading the water over a larger neighbouring surface area to improve soil moisture and increase agricultural production (spate irrigation). In-situ technology consists of collecting and making storage available in areas within the landscape where the water is going to be utilised.
Surface water harvesting - at small or large scale - provides opportunities for reviving and improving the soil (moisture) productivity and allows for crop cultivation, afforestation and livestock production. It is also used to prevent erosion and land degradation and to promote ecosystem recovery.

Groundwater harvesting refers to techniques that increase the quantity of water that (artificially) infiltrates into the sub-soil (recharge) and / or keep groundwater available for longer periods. Options for increasing groundwater recharge include constructing small dams or bunds, terracing, contour trenching, sub-surface dams and planting trees or vetiver grass. This can improve water for domestic use or for irrigation, livestock or aquaculture.
Recharge of the sub-soil and of aquifers is vital in order to maintain shallow groundwater levels and the flow towards wells. Recharge is either natural or results from human intervention. Groundwater storage is an important component of the water supply chain and an important alternative to surface water storage behind dams. Managed Aquifer Recharge (MAR) can be used in conjunction with water harvesting techniques to recharge an aquifer by catching water during rainfall, reducing rapid runoff out of a catchment area.

The **most common techniques** are the following:
- Pits, bunds, trenches and vegetation lines, such as shrubs and vetiver grass, to trap water along slopes.
- Ponds and reservoirs with permeable bottoms, promoting infiltration into the sub-soil or aquifers.
- (Sand) storage dams: behind these dams a new body of sand is deposited, creating additional groundwater storage capacity.
- Sub-surface dams in highly permeable riverbeds: preventing groundwater from being drained away.

A sand dam will enlarge the storage capacity, while a sub-surface dam optimises the existing storage capacity under the surface. A sub-surface dam allows for water-resources development in regions where the construction of surface dams is difficult due to geological conditions. In general, sub-surface dams are used when the topographical gradient is low while sand dams are used when the topographical gradient is high.
Physical conditions should be carefully ascertained before construction, including average rainfall, flow rates of rivers / streams or drainage lines, porosity and texture of the soil, water salinity, aquifer storage capacity, and depth of the impermeable layer. It is important to consider downstream effects, as dams have an impact on the natural flow of rivers and groundwater.
Proper operation, regular maintenance and cost recovery are important factors for success of communal systems, but often neglected. Regular inspection, cleaning and occasional repairs are essential. These activities should be controlled by local communities to ensure local ownership and sustainability.

Waste or grey water harvesting refers to systems that collect and recycle waste water for small-scale agriculture. More on this topic can be found in the booklet *Smart Sanitation Solutions*.

Besides the available water sources, water harvesting techniques also include options for collection, storage, treatment and use.

Water collection

Collection techniques include:
- Nets for intercepting fog.
- Sheets and hardened surfaces (roofs) for direct collection of rainwater.
- Wider surface areas, terraces, pits, bunds, trenches and vegetation strips for collection of overland flow.
- Natural depressions, check dams, sand dams or flood diversion structures for streams.
- Sub-surface dams for groundwater.

In some cases, there is an **intermediary structure / device** between collection and storage, such as:
- Gutters and drains that transport rainwater from rooftops or hardened surfaces.
- Devices which drain the first collected rain, preventing contamination.
- Sand traps at inlet points of surface reservoirs.
- Infiltration wells or 'oases' to transfer surface water into groundwater bodies.

Water storage

Water can be stored in artificial constructions (e.g. water tanks, drums, jars, jerry cans, cisterns), in surface reservoirs (ponds, dug-outs, artificial reservoirs) and in the sub-surface as soil moisture or groundwater. The use of sub-surface storage in aquifers is relatively unknown but offers advantages with regard to storage volumes and natural filtering. Groundwater is often of good quality, but needs checking for possible contamination and for mineral contents above WHO standards (salinity, nitrate, iron, fluoride, arsenic).

General comparison of storage means:

Characteristics	**Closed constructions** *(water tanks, drums, jars, jerry cans, cisterns)*	**Surface reservoirs** *(ponds, dug-outs, artificial reservoirs)*	**Sub-surface reservoirs** *(soil moisture, aquifers)*
Volume	Small	Small to moderate	Large
Scale	Household to small community	Community level	(Multi-) community level
Price per stored m^3	High (small volumes)	Medium	Low to variable (large volumes)
Evaporation loss	Low when covered	High	Low
Leakage	Little	Variable	Variable
Water quality	Initially good	Variable; generally unfit for drinking without treatment	Good; generally fit for drinking if protected
Vulnerability to contamination, algae growth and warming	Vulnerable	Very vulnerable	Purification capacity and cool
Diseases	Possible habitat for vectors of tropical diseases such as mosquitoes	Habitat for vectors of tropical diseases such as mosquitoes, Guinea Worm, Bilharzias	Safe (except for human and livestock pollution)
Suspended materials	Settlement	Settlement	Filtering
Environmental impact	No direct impact	Medium improved soil moisture, erosion prevention and eco-system restoration	Improved soil moisture, erosion prevention and ecosystem restoration
Points of attention	Keep water cool, dark and covered	Risk of clogging	Risk of clogging
		Becoming more salty by evaporation Environmental and social impacts	Dilution of brackish groundwater Pollution prevention by livestock and humans
Abstraction	Easy access	Special abstraction device, preventing pollution	Abstraction wells, scoop holes and pumps
Requirements	Wide applicability	Requires proper siting and skilled design (e.g. for dam safety)	Requires pre-study (infiltration capacity, likelihood of getting shallow aquifer), proper siting and skilled design
Maintenance	Moderate	High (after floods)	Variable
Actual use	Widespread and attractive	Widespread	Often undervalued

Water treatment and use

Although most of the small-scale water conservation and water harvesting measures have a positive impact on ecosystems, water (or lack of it) can play a crucial role in the transmission of diseases in various ways. Storage tanks and surface water reservoirs may host disease vectors: mosquitoes for malaria and dengue, snails for bilharzia and larvae for guinea worm. Hookworm spreads easily in muddy areas. Algae grow in nutrient-rich, still and shallow water exposed to sunlight. Fish and frogs may have a positive impact, although some fish make reservoir water turbid. Excess standing water can lead to health hazards and be contaminated by livestock.

If collected water is used for drinking and cooking, it is essential to monitor the quality and water treatment is advised. Information about treatment techniques can be found in the booklet *Smart Water Solutions*.

It is recommended that a basic water quality test is carried out on collected rainwater during the first year following the completion of the harvesting infrastructure. Further testing, including for the presence of mosquito larvae, is necessary whenever the quality of the water is in doubt.

Important **preventive measures** include:
- Keeping catchment areas like rooftops clean.
- Preventing the first dirty flush entering tanks (diversion structure).
- Covering tanks and open wells.
- Fencing off catchment areas (e.g. by thorn bushes) to prevent animals from contaminating harvesting areas.
- Marking protection zones.
- Hygiene awareness and practice (education).
- Removing breeding places for mosquitoes, snails and larvae.
- Regularly testing the water quality.

What makes water harvesting solutions smart?

The technologies described in this booklet have successfully been practised at relatively low costs and in various climates in developing countries. Optimal use is made of the available water resources above and below the soil surface, preventing unnecessary loss of water.

A water harvesting technology is 'smart' when adapted to **local conditions** and adaptable to a changing environment. Smart Solutions meet the needs of the user, are possible to replicate at a larger scale and are simple to implement, use, maintain and repair. More over, the techniques are affordable.

Some success factors can be identified for water harvesting techniques.
However, successful replication and implementation depends on local conditions.

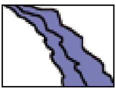
Success factors:
Start small, learn as you go, expand as needed; introduction takes time.
Build on existing practice, experience and infrastructure (don't re-invent the wheel).
Focus on local construction materials, local knowledge and techniques, local labour.
Recognise local customs, social structures and habits.
Consider existing institutional settings (develop institutional support).
Ensure political commitment.
Find an 'ambassador'.
Involve local stakeholders in design and planning (developing ownership and skills), including women.
Organise operation and maintenance: simple, local, affordable, low frequency, accessible services, e.g. performed by water committees with balanced representation.
Ensure proper local training, capacity building.
Secure property laws / ownership; own benefits, motivation, financing mechanisms.
Evaluate capital resources, loans, micro-credits.
Recover costs; make choices based on affordability and willingness to pay.
Ensure strict and fair collection of revenues / water tariffs / taxation in relation to benefits.
Respond to actual needs (demand responsive).
Build on co-operation successes in communities.
Inspire by showing results / successes of other projects.

All 17 water harvesting techniques described in this booklet represent examples from different parts of the world, which are effective within particular settings and contribute to an improvement in socio-economic conditions. The aim of this booklet is to inspire local initiatives, by learning from experiences and adapting them to the local context.

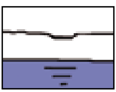
Each case provides a short description of the technique, applying conditions, advantages, considerations, costs and references. Costs are approximate as they are time specific and highly dependent on local conditions, such as availability of labour and materials, physical conditions and required transport. The price of water is even more difficult to estimate since it is also affected by water losses, the lifespan of a structure and the frequency of refilling the system.

The various techniques are presented in three groups, based on a combination of the available water source and the medium in which it is stored:

The first three techniques describe fog and rainwater harvesting and storage.



The following five examples focus on runoff or surface water harvesting, concluding with an intermezzo.



Lastly, eight techniques on groundwater recharge are presented.

Fog water collection, Nepal, Peru and Chile

Fog interception technology copies the function of trees and other natural features. It uses large polypropylene mesh nets on ridges, erected perpendicular to the prevailing wind, to capture water-loaded fog, which forms in humid months in mountainous regions or coastal areas. The mesh captures water droplets (1 to 40 μm), which trickle into a collection trough and drain into a series of tanks.

Large collectors are usually 12 m wide and >4 m high. The mesh covers the upper 4 m of the collector, giving a collecting surface of 48 m^2, providing fresh drinking water for rural communities. Typical water production rates from a fog collector range from 150 to 750 litres per day but some schemes are capable of producing 2,000 to 5,000 litres per day. If sufficient water is collected, vegetation or crops can also be planted and sustained. Once vegetation is established, it can sustain itself by catching the fog droplets directly.

Applying conditions:

- The technique is suitable for locations with frequent fog periods. Upland areas where fog is produced by the advection of clouds over the terrain or where clouds are forced to rise over mountains are most suitable. Fog formed on the ocean surface, or nocturnal radiation fogs in low-lying areas normally lack sufficient liquid water content or sufficient wind speeds for substantial water collection.
- A number of meteorological and geographic considerations are important in choosing a site: predominant wind direction, clouds forming below the maximum terrain height, sufficient space for the fog collectors, and no major terrain obstacles. In the case of coastal cloud decks, the mountain range should be within 5 or 10 km of the coast.

Advantages:

- The project costs are low, the technology and maintenance are simple.
- Water of very good quality.

Interception nets for fog harvesting, Nepal (photo: B. van de Wilt).
Insert: Local people collect the harvested fog water, Nepal (photo: Simavi).

Considerations:

- Frequent fogs are needed. Examine meteorological records and consult local people about their observations.
- Relatively small water quantities can be harvested.
- Efficiency of collection improves with larger fog droplets, higher wind speeds, and narrower collection fibres / mesh width. In addition, the mesh should have good drainage characteristics.
- A polypropylene mesh has a lifetime of about ten years.
  In Nepal, operation and maintenance is difficult due to the unavailability of spare parts (mainly polypropylene mesh). Hence keeping stock of mesh and other spare parts is highly recommended.

Costs:

- Material: Polypropylene mesh per 1 m^2 (Peru and Chile)	US$ 0.25
- Labour: construction and installation of large fog collectors, reservoir tanks and taps:	
- Skilled labour: 140 man days (Nepal)	US$ 4 per day
- Unskilled labour: 400 man days (Nepal)	US$ 2.75 per day
- All inclusive (materials, labour):	
- Fog collectors including building materials:	US$ 100 - 200
- 48 m^2 fog collector providing 3 l/m^2/day:	US$ 378
- Cost per m^2 (Nepal, including reservoir and tap):	US$ 60

Information:

www.simavi.org
www.fogquest.org
www.msc-smc.ec.gc.ca
www.newah.org.np
www.idrc.ca

Interception nets for fog harvesting, Nepal (photo: M. Cornelissen).
Insert: Harvesting fog water (photo: Simavi).

Storage tanks for rooftop harvesting, Brazil and Nicaragua

Rooftop rainwater harvesting enables households as well as community buildings, schools and clinics to manage their own water supply for drinking water, domestic use, irrigation and other income generating activities. The technique and its components are described in the previous chapter 'The elements of water harvesting'.

In Ocara, Brazil, rainwater tanks have been constructed of **concrete blocks**. The tanks are partly (1.5 m) build below the soil surface. These tanks can store up to 20,000 litres of water, each supporting 1 to 3 families with a water supply for domestic use and food-growing (cultivation of peppers). The tank is covered with a concrete top and small fish keep the water free of insects. Following successful implementation of 40 community rainwater tanks, another 80 tanks are planned at household level.

A low-cost option is the **brick cement tank**, used in Nicaragua, Ghana and other countries. It is produced with local bricks, cement and steel wire. In general it is cheaper than ferro-cement tanks and easier to build. Volumes can be 0.5 to 30 m^3. Brick cement tanks are constructed by placing an upright ring of bricks in a circle, with 3 rings of steel wire tightened around them. If the tank diameter is bigger than 2 meter more rings are needed. A second, third and fourth ring of bricks are added and suitably tightened. Cement is then applied on the inside and outside of the brick walls and to cover the bottom. A metal or PVC outlet pipe can be installed at the bottom. Once the cement has been applied, the tank needs to be covered with paper or plastic and kept wet for 7 days to cure the cement. Another curing option is to fill it up after the second day of installation.

Applying conditions:

- If used for rooftop harvesting, an annual rainfall of at least 100-200 mm is required.
- Storage tanks can also be filled up by pumps and be used for domestic use or irrigation.
- Brick cement tanks can be constructed with 1 bag of cement per m^3.
- The bigger the volume of the tank, the lower the amount of materials (cost) per m^3.

Construction of a large storage tank with concrete blocks, Tanzania (photo: Simavi).
Insert: Construction of a small brick cement tank, Mozambique (photo: Practica).

Considerations:

- Tank maintenance consists of physical inspection and repairing cracks with cement. It is advisable to first construct a small tank before attempting a large one.
- Several studies have shown that water from well-maintained and covered rooftop tanks generally meets drinking water quality standards. Maintenance practices are however crucial, including removal of debris and overhanging vegetation from gutters and the roof, and preventing water from stagnating in the gutters.
- Basic water quality testing is recommended during the first year, with further testing when water quality is in doubt. A low cost water test is the 'HACH' pillow test, about US$ 1 per test.
- Managing microbiological quality consists of treatment if contamination is suspected or when water quality needs to be guaranteed.

Costs:

- Brick cement tank of 1 m^3: 1 bag of cement, 100 bricks, 1 kg of wire	US$ 20
- Brick cement tank of 6 m^3: 3 bags of cement, 300 bricks, 3 kg of wire	US$ 40
- Plastic lined tank of 5 m^3:	US$ 50
- Sub-surface ferro-cement tank of 60 m^3:	US$ 1,900

Information:

www.practicafoundation.nl
www.braziliezending.nl
www.emas-international.de
www.gaia-movement.org
www.margraf-publishers.net
www.rainwater-toolkit.net
www.unep.org/depi/rainwater
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www.arrakis.nl
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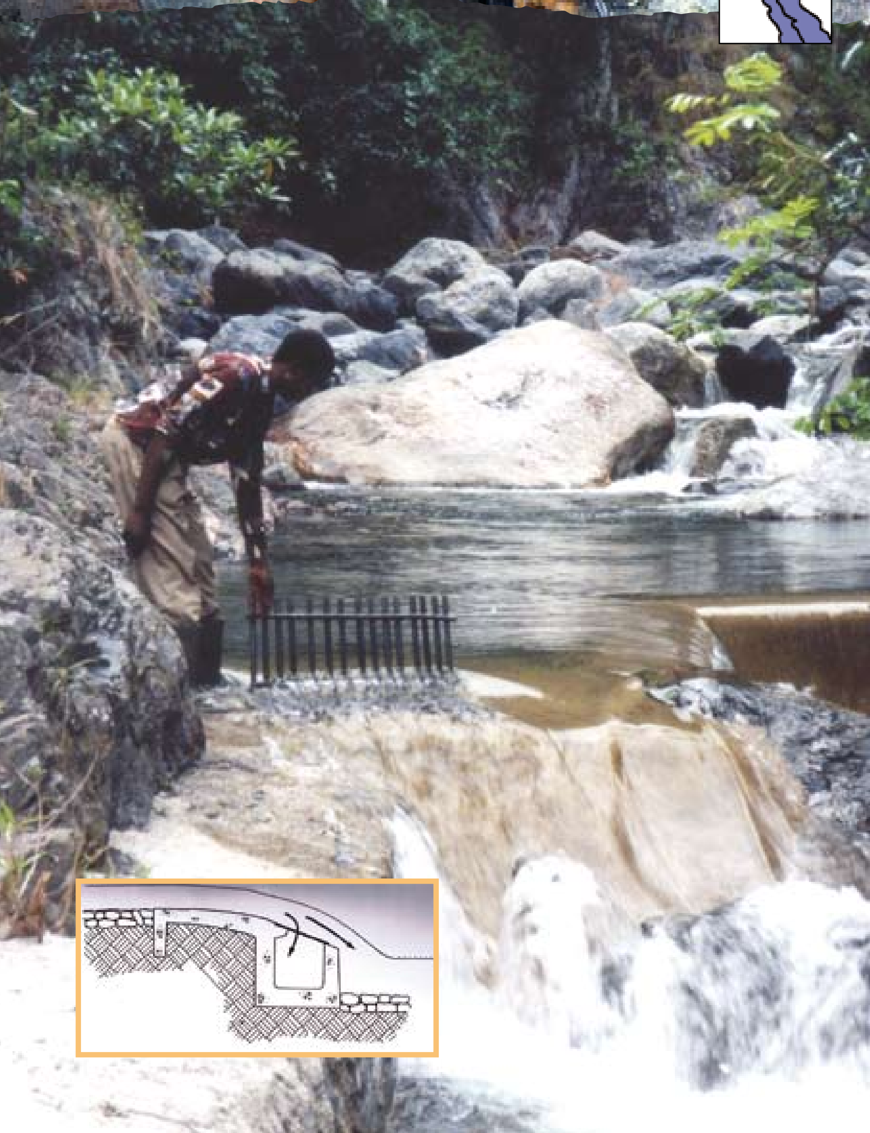
www.harvesth2o.com
www.practicalaction.org
www.ropepumps.org

Roof catchment and storage tank at a school, Kenya (photo: Simavi).
Insert: Ferro cement water tank used at household level, Brazil (photo: St. Braziliё Zending).



Tyrolean weir or Bottom intake from streams, East Africa

Dams and water inlet structures in embankments are vulnerable and expensive elements in river-fed water systems. They are easily damaged by floods, underflow, seepage and suffer from build-up of sediment or rubbish in the water.

The Tyrolean weir forms a more reliable and cheaper alternative. Water is abstracted through a screen (or inlet) over a gutter, usually made of concrete and built into the riverbed. The screen on the crest should slope downstream (15-30 degrees), to increase flow velocities and prevent sediment carried by the stream from blocking it. From the gutter, water enters a pipeline, which drains into a sedimentation tank and then flows by gravity into the rest of the system.

Applying conditions:

- Tyrolean intakes are used in small permanent rivers and streams where the sediment content and bed load transport are low, or on the crest of a dam spill.
- The threshold can be a concrete elevation above the rocky bed of a mountain stream, or a vertical low weir structure, anchored in the embankment.
- The capacity of the inlet pipe / drain (diameter and gradient) should be 30% more than the design flow and have an uniform gradient to prevent accumulation of sand.
- The sedimentation tank can accumulate 1.5-2 m^3 of deposits and allows water to filter for 10 to 30 minutes at very low speed. It is cleaned by washing it out.

Considerations:

- The weir or intake should be carefully sited.
- The weir itself does not clean or purify the water.
- Regular inspection and cleaning of the grit / rack and possibly the gutter and sedimentation tank is required during and after storm periods.

Costs:

- Material (excluding the pipe and sedimentation tank): US$ 300 - 600.
- Labour (if site is easily accessible): 30 - 50 man days.
- Operation and maintenance: several visits per year for inspection, cleaning and minor repairs. Overall easy to carry out due to low-tech structure and the use of local labour and materials.

Information:

info@aquaforall.nl www.aquaticmanagement.com

Man checking the grid at a Tyrolean weir, Tanzania (photo: D. Bouman, Aqua for All).
Insert: Cross section of a Tyrolean weir (Intermediate Technology Publications).

Surface runoff harvesting, Borana Zone, Ethiopia

In Ethiopia's water-scarce Borana Zone, rainwater and surface runoff harvesting has been effectively used to provide a substantial quantity of water which is used by rural communities for drinking and domestic purposes, for livestock and crop growing. Surface runoff water during rainy periods is collected in a tank below ground surface, channelled there by bunds and gutters. Runoff capacity can be increased by reducing vegetation cover, increasing the land slope with artificial ground cover and reducing soil permeability by compacting the ground.

Applying conditions:

- Minimum annual rainfall of 100-200 mm.
- Storage tanks are typically made of bricks and coated with cement.
- Siting of the tanks:
  - close to the area of cultivation to enable ease of irrigation.
  - not in close proximity to large trees as roots may cause cracking.
  - away from houses or paths / roads to prevent contamination and people or animals from accidentally falling in. Additionally, a fence (e.g. from thorn bushes) can be constructed around the tank.

Considerations:

- A series of sedimentation basins minimises the silt load of the runoff water.
- Cover the water inlet behind the sedimentation basins with a mesh-wire or nylon screen.
- A maximum tank height of 1.75 m is recommended to withstand the water pressure and to make cleaning and use easier.
- Covering the tank is recommended to prevent evaporation and contamination.
- When water is used for drinking, basic water quality tests should be carried out.

Costs - surface water runoff harvesting tank of 50 m^3:

- Material:	US$ 4,200
- Transport and communication (study, supervision, training):	US$ 150
- Labour: - Professional labour: 530 man days (Ethiopia)	US$ 12.5 per day
- Local contribution: 65 man days and in kind contribution	
- Cost per litre:	US$ 0.13

Information:

www.rainfoundation.org www.practicalaction.org

A woman collecting stored runoff and rainwater with a pump, Ethiopia
(photos: RAIN foundation).

Finger ponds, Lake Victoria, East Africa

Finger ponds use innovative techniques to enhance the natural productivity of wetlands and floodplains. The ponds consist of stretched artificial ponds 5 to 12 m long, extending into the wetland like fingers, hence the name.

Finger ponds are excavated at the upstream edge of naturally occurring wetlands or floodplains and are lined with PVC plastic to prevent the water running out. They fill up during the flood cycle, and trap fish within them as the flooding recedes.

Fish are grown in the ponds during the dry season and can be caught to provide additional protein for local communities. The ponds can be enriched with manure. Meanwhile the land between the ponds is cultivated with seasonal crops.

Pilot projects with finger ponds are being undertaken to assess their potential productivity, suitability and sustainability, taking into account natural and socio-economic aspects.

Water that otherwise would run off or evaporate is now stored in these finger ponds during the dry periods. The annual inundation provides opportunities for aquaculture, fish cultivation and small-scale crop cultivation through irrigation.

Advantages:

The finger ponds allow for fish cultivation and provide additional protein, crops and income for local communities.

Considerations:

Maintenance consists of cleaning or desilting the ponds by swabbing the pond bottom.

Applying conditions:

- Wetlands or floodplains where water collects naturally.
- The local morphological situation dictates the specific requirements, costs and time needed for excavating the ponds.

Costs:

Depending on local situation and size of the ponds.

Information:

www.wetlandprofessionals.org www.unesco-ihe.org
www.ihe.nl/fingerponds

Trapping fish during a period of high floods, Bangladesh (photo: B. van Waes).

Pond farming, Bolivia

The first farm ponds in Bolivia date back to the 1980s, when 'k'hochas' (small water reservoirs that the farmers had dug) were enlarged with the help of heavy machinery. Rainwater is collected in these farm ponds, taking advantage of the runoff from the higher slopes or water from a nearby watercourse during periods of rain. The pond water is used for irrigation and keeping fish.

Although different local organisations had different working methodologies and pond designs, there was an exchange of ideas between them, one of which was to encourage farmers to make a 10 to 30% contribution towards their pond construction. Some organisations chose to build ponds for collective use, but - as these often encountered problems of ownership and maintenance - individual ponds proved to be a better option.

Pond farming is now promoted elsewhere, following successful experiences in Bolivia. As ponds and pond farming become more widely known, they are becoming more accepted.

Costs:
- Material: pond 1,000 m^3: US$ 200 - 1,600
- Labour: average 14 man days.

Information:
www.snvworld.org

Sketch diversified pond farming, Bolivia (M. Verweij, SNV).
Insert: Pond to collect surface runoff, India (photo: Velugu).

Spate irrigation, Pakistan

Spate irrigation is an ancient form of water management in arid and semi-arid environments, practised most widely in Pakistan, but also in Asia, Yemen, the Horn of Africa and North Africa. It is typically applied where highland plains meet alluvial flat slopes and where annual rainfall is erratic, often below 200 mm.

In Pakistan, sporadic floods from temporary rivers are diverted and spread over a large area of land by earthen bunds, about 1 km long, several metres high and up to 20 m wide at the base. Near the mountains, the bunds divert part of the fast flowing flood; lower down they divert the entire flow. Water is guided through a system of flood channels to the bunded fields, often as large as 15 hectares, sub-divided into sections. The collected water is used for irrigation, the filling of water ponds and the recharge of groundwater. As such, spate irrigation provides considerable opportunities for reviving and improving the agricultural productivity and livestock production.

Advantages:

- Large systems can be constructed manually with local materials and small civil works.
- Control over floodwater and sedimentation reduces flooding and gullying downstream.

Considerations:

- Lowland systems depend on the water supply from their upper watershed.
- Spate irrigation and pond farming systems are risk-prone, due to the unpredictable floods and frequent changes in the riverbeds from where water is diverted.
- The management of sediment loads is as important as the management of flood water.
- Soil moisture conservation (recharge of shallow aquifers) is the key to high productivity.
- Construction and maintenance requires considerable human and animal labour or the use of tractors and bulldozer and consequently a strong local organization.
- Spate irrigation is associated with big income fluctuations between good and bad years.
- There is scope to improve the productivity of spate irrigation through improved traditional engineering, field-level management, and new or improved crops.

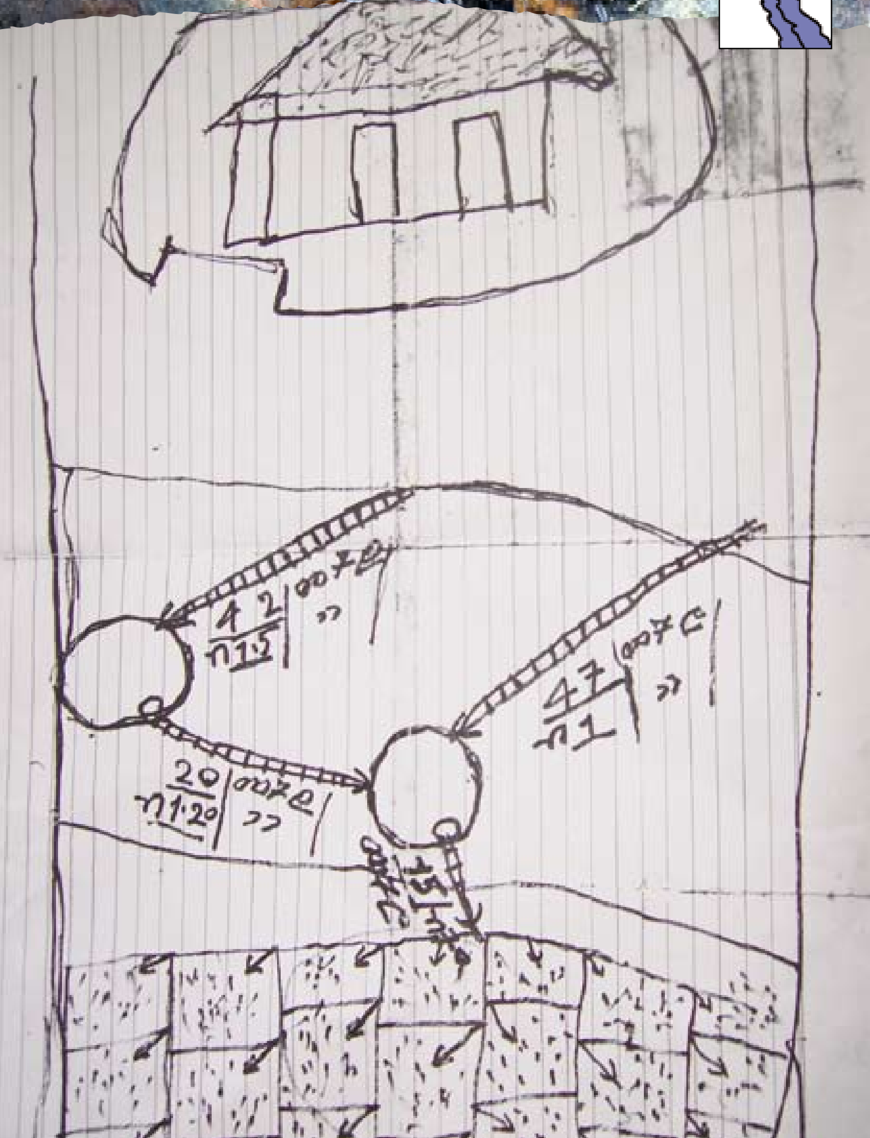
Costs:

- Material (improved traditional structures):	US$ 10-300/ha.
- Operation and maintenance:	US$ 10-40/ha per year.

Information:

www.spate-irrigation.org
www.metameta.nl
www.metafro.be
www.leisa.info

Maintaining earthen bunds with bullocks, Eritrea (photo: F. van Steenbergen).
Insert: Flooding at wadi siham, Yemen (photo: Sharafaddin).



The story of a smart water harvester in Tigray Region, Ethiopia

The Central Zone of Tigray Region in northern Ethiopia is a highland area with irregular rainfall of not more than 600 mm annually. The wet season lasts from July to September / October and is followed by a long dry season. Local farmer Abadi Redehey has less than 0.5 ha of cropland on reddish and clay soils to sustain his family. He has to be innovative to solve drainage problems on his sloping lands and improve crop productivity. On a visit to the town of Axum, Abadi observed the sewerage system, which drained water in open canals rather than letting it remain on the soil surface as was happening on his farm. After seeing this, he began to dig canals to ensure drainage, capturing excess runoff water and groundwater from deeper levels.

This innovative farmer excavated long, deep canals diagonally across the slope and placed long, flat stones down both sides of the canal to help the water pass easily. Finally, he placed more flat stones on top as a cover, covering them with soil. The canals now lie 40 to 180 cm under the soil surface.

The water is led through the canals to dug pits with earth walls. These water-collection points fill up in 8-12 hours during the wet season, and the excess water drains to a nearby small river. During the dry season, water from the pits can be drawn out for irrigation, using a treadle pump.

Abadi discussed his ideas and practices with other farmers and gradually expanded the system throughout the plot, connecting canals and leading the water to three collection points. He is now able to get three harvests per year from his plots: a cereal crop during the wet season and one or two harvests of vegetables such as cabbages, onions, garlic, lettuce and tomato during the dry season. He also grows some fruit trees on his farm such as guava, orange, mango and lemon and earns some additional income by selling onions on the market.

He has diversified his cropland and livelihood and can now ensure food security for his family. He made his innovation using entirely his own resources and at his own expense, in terms of materials and time.

Sketch of collecting canals made by Abadi Redehey (photo: Hailu Araya).

Abadi and other local farmers were invited to a workshop in Axum to present their innovations. Abadi made a diagram sketch to explain how he manages the water during the wet season and manages its scarcity during the dry season. Other farmers expressed keen interest in his system of removing excess water and storing it for later use. This innovation was selected for further study in a participatory innovation development process.

Abadi and three other farmers formed a farmer research group to study how effective this innovation is in different farm settings, and to provide training for other farmers. During the wet season regular meetings were held to observe, discuss and plan activities, as a form of monitoring and evaluation. Sometimes outside experts joined their meetings to advise, research and document the drainage technology and to ensure broader implementation. Giving recognition to the farmers' creativity is the entry point for participatory research and development, in which farmers are seen as genuine partners with a lot to offer and in which the farmers are also open to receiving ideas from people who respect them.

Abadi is proud and happy to be listened to by district administrators, experts and farmers. 'Now many people - including officials and educated people - respect me,' he said.

Information:

www.prolinnova.net

'Explanation of technology, sharing of knowledge and inspiring others are important success factors' according to farmer Abadi (photo: Hailu Araya).
Insert: Farmers and development agents discussing farmer's innovation at an agricultural show in Tigray, Ethiopia (photo: Hailu Araya).

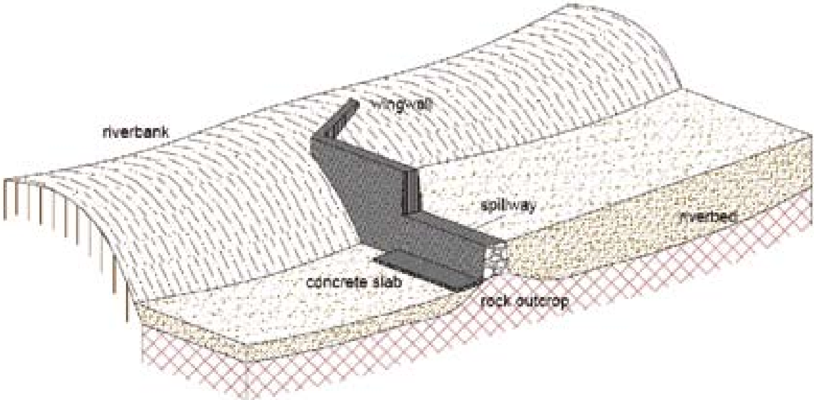
Sand dam, Kitui, Kenya
In Kitui, Kenya, 'sand dams' are placed across a bed of intermittent small rivers, consisting of a 1.5-2 m high impermeable barrier. In fact, this barrier is built from stone or concrete, placed on a firm impermeable layer of rock or clay. During periods of high flow, sand and gravel accumulate here, giving the dam its name.

Runoff water infiltrates these highly permeable deposits and the bordering riverbanks, creating an artificial aquifer, which can store up to 35 % of its total volume as groundwater. Water is captured through a scope hole, hand-dug well or tube well, supplying water to nearby villagers in the dry season.

Applying conditions:
- Intermittent rivers in regions with semi-arid climates and erratic but intensive rainfall.
- Sandy riverbeds experiencing high sediment loads after heavy rain storms.
- River valleys with gradients between 1% and 2% are favourable.
- The dam location should be chosen carefully to ensure the highest storage capacity and convenience at minimum cost.

Advantages:
- Clean, good quality water due to the filtering effect of sand.
- Underground storage means limited evaporation, less chance of pollution and no breeding of surface-water disease vectors.
- During a period of serious drought, some dams still provide water.
- Water is also stored in the riverbanks. Through the increased base flow from the banks, the riverbed can be recharged during the dry season.
- Low maintenance (costs) and long life.

Sand dam in dry season in Kitui district, Kenya (photo: Borst & Haas).
Sand dam overflowing in wet season in Kitui district, Kenya (photo: M. Hoogmoed).


riverbank
wingwall
spillway
riverbed
concrete slab
rock outcrop

Considerations:

- Expert input is required to determine the best site. Problems primarily relate to aspects of dam locations and construction.
- Risk of erosion and contamination during the rainy season.
- Accurate estimation of the groundwater reserves is difficult.
- Dams made of concrete, stone-masonry and brickwork require skilled labour for construction, but are stronger and have a longer lifespan.
- The construction of sand dams in cascades improves total storage and efficiency and minimises seepage losses.
- The effects of sand dams on downstream river discharge are generally small (< 10% of runoff).
- Regular checks and repairs are required after floods.

Costs (2006):

- Material:	US$ 5,500
Other costs:	US$ 500
- Labour:	
- skilled:	US$ 2,500
- unskilled:	900 man days

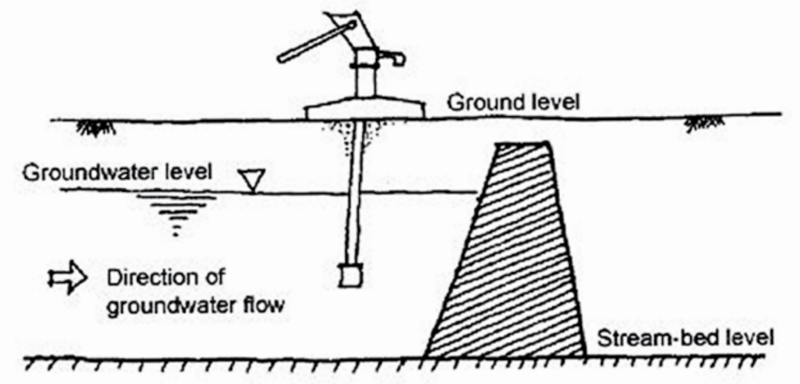
- Operation and maintenance: 5 days per year

The construction of dams is largely carried out by the local community. Costs mainly relate to local availability of cement, masonry and professional supervision.

Information:

sasol@kenyaweb.com
www.unep.or.jp
www.waterforaridland.com
www.acaciainstitute.nl
www.iah.org/recharge

Sketch of a sand dam (Sander and Borst).
Constructing a sand dam in Kitui district, Kenya (photo: M. Hoogmoed).


Ground level
Groundwater level
Direction of groundwater flow
Stream-bed level

Sub-surface dam, Pernambuco, Brazil

The use of sub-surface dams in naturally occurring alluvium creates groundwater storage upstream of the dam, raising the water table and preventing evaporation losses. A sub-surface reservoir in Pernambuco has an average depth of 4 m, is 50 m wide and 500 m long, storing about 4,000 m^3 water.

A sub-surface dam is constructed across a valley in a seasonally dry sandy riverbed, by digging a trench down to the bedrock or other impervious layer. The dam, which is placed in the trench, may consist of a wall or screen and covered with excavated material until it is completely concealed. The refill material must be properly compacted.

Applying conditions:

- Seasonal rivers in semi-arid regions with permeable sediments and an impervious layer at a shallow depth (maximum 3 to 4 m deep).
- River valleys with gradients of between 1 and 2% usually enable the highest storage.
- Ideal where groundwater flow converges from a large catchment into a narrow passage.

Advantages:

- Sub-surface dams are not likely to deteriorate, with little danger of breaching.
- Constructions have a long lifespan and require minimal maintenance.

Considerations:

- To prevent seepage through the dam, plastic canvas can be used. Plastering mud-and-water on the downstream side of the trench is recommended to smooth the slope cut and to prevent sharp stones and roots from puncturing the fabric.
- Leakage is often difficult to detect.
- Impact of the changed groundwater flow on the downstream area.
- If the groundwater shows increased salinity during the dry season, a discharge pipe could be placed at the bottom of the dam, to allow annual drainage of dissolved salts.

Costs - sub-surface dam (Brazil) of maximum 4m depth and 40 m length (2001):

- Material costs & construction:	US$ 1,400
- Feasibility study:	US$ 200
- Technical support:	US$ 275
- Operation and maintenance:	low

Information:

www.acaciainstitute.nl
www.iah.org/recharge
www.worldbank.org
www.waterforaridland.com

Sketch sub-surface dam (Nissen-Petersen), Construction of a small dam (photo: S. Mutiso, Sasol), Drinking water pump to collect harvested groundwater, Kenya (photo: A. de Vries).

Percolation ponds, India

Unlike surface reservoirs, percolation ponds are specifically designed to recharge groundwater through the bottom of the pond. Water is stored in shallow artificial ponds with permeable sandy, gravel or rock beds, so that it filters slowly through to an aquifer below. The ponds can also be used as a direct source of irrigation water and for fisheries.

A percolation pond is constructed by excavating a depression, forming a reservoir, or by constructing an embankment in a natural ravine to form an impounded reservoir. Ponds are generally 1-4 m deep, deep enough to prevent excessive algae or water plant growth, and shallow enough to prevent anaerobic conditions developing at the bottom. The bottom of the pond must be regularly inspected and treated to minimise clogging of sediments and keep evaporation losses to a minimum.

Stagnant surface water is easily affected by bacteria and disease vectors, and should be used only for irrigation or for livestock. However, the infiltrated water recharging the groundwater can be of good quality, as many pollutants are filtered out. Groundwater recharge or effectiveness varies from 35 to 75% with an average of 50%. Highly porous and fractured basalts show good efficiency.

Applying conditions:

- Percolation ponds can best be applied in semi arid regions, perferably where sediment loads are low, the ground is permeable and groundwater levels are shallow.
- Maximum capacity (India) between 10.000 – 15.000 m^3, normally about 2-3 fillings per year. Supply channels carrying runoff water to the pond can increase their capacity.

Considerations:

- Percolation ponds require a relatively large surface area.
- Ponds can easily silt up, reducing the infiltration to groundwater (clogging).
- Scheduling sufficient 'rest' periods between flooding periods allows for drying and biodegradation of clogged layers, and removal of material.
- Vetiver planting along major inflow paths can function as a sediment trap.

Costs:

Percolation pond, capacity 10,000 - 15,000 m^3 (India)	US$ 5,000 - 15,000

Information:

www.simavi.org
www.cgwb.gov.in
www.cabmphandbooks.com

Storage and groundwater percolation pond, used for refilling tank wagons and washing, Burkina Faso (photo: J. Worm).

Inserts: Check dam in Dalassa Catchment, Sudan, functioning as a direct water source and as an infiltration pond for a nearby well (photos: A. van Wessel, Aqua for All).

Vetiver contours, Zambia, Mozambique and Zimbabwe

Vetiver contours are a low-cost measure for reducing soil erosion and improving the soil water content and groundwater recharge. Vetiver is a non-invasive grass with a very deep root system that is able to grow under nearly all conditions and even survives fires. Vetiver rows along the contours of a slope prevent much of the rainwater from flowing downhill, allowing the water to penetrate the soil, and making it available for crops and groundwater recharge. Topsoil that would otherwise be washed away from the field now accumulates in front of the vetiver contours.

A contour row of grass plants should be made for every metre of height difference or every 10-20 metres along the slope. The individual vetiver grass plants are planted along the contours, at a distance of about 15 cm apart. A double vetiver plant row is most effective and will form a closed fence within 1-2 years. Once the vetiver contours have been established, little maintenance is required.

Besides preventing erosion and allowing water to infiltrate the ground, the grass can be harvested and used for thatching or handicrafts. The vetiver roots can be used in perfume. Vetiver grass does not spread seeds, and will therefore not spread into the fields. Cattle dislike this type of grass so they will not eat it.

Applying conditions:

Vetiver contours or alternative local grasses are suitable in many regions. They are of particular benefit in sloping areas where heavy rainfall results in erosion of fertile top soils.

Considerations:

- Vetiver nurseries are simple to establish in humid areas, including those areas where normal crops will otherwise not survive periods of flooding.
- Densely planted vetiver strips can be used as natural barriers around surface water ponds to prevent livestock from entering the water.

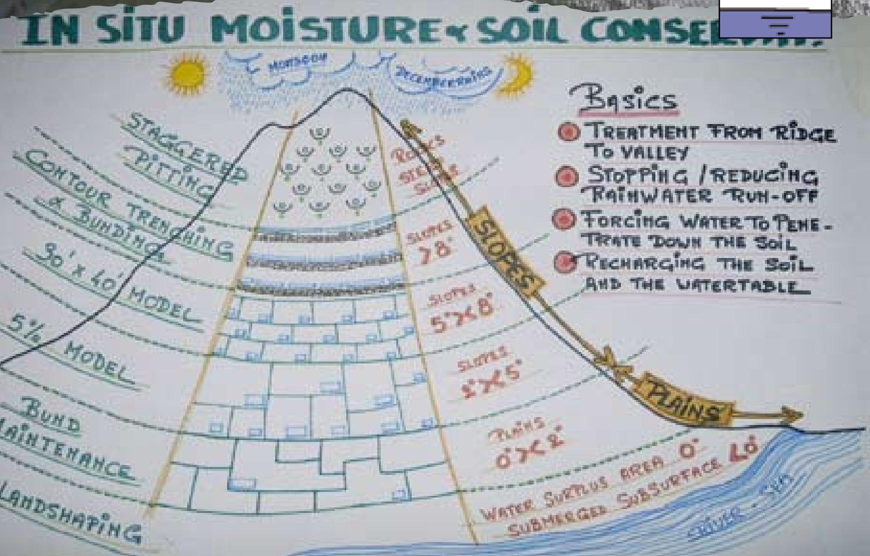
Costs:

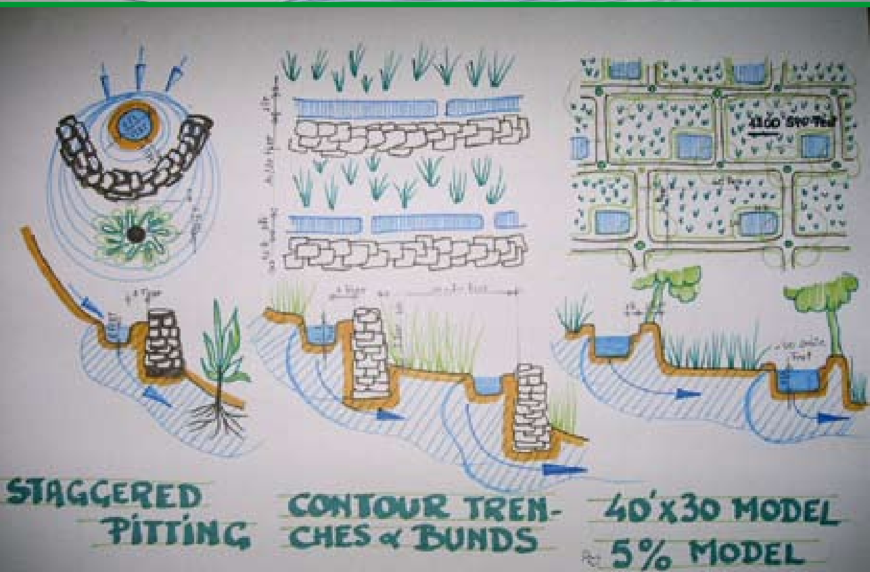
- Material: 1,000 vetiver slips from local farmers: US$ 20 (excluding transport)
- Labour: 2 man days for 100 m of contours from slips (US$ 1-1.5 per day)
- Maintenance: low, 1 day/year per 100 m for filling up gaps and cutting it down.

Information:

www.vetiver.org www.gaia-movement.org

◀ Vetiver contours along a slope prevent much of the soil and rainwater from flowing downhill in the Gwembe district, Zambia (photo: Gaia).


IN SITU MOISTURE & SOIL CONSE…
MONSOON
Basics
TREATMENT FROM RIDGE TO VALLEY
STOPPING / REDUCING RAINWATER RUN-OFF
FORCING WATER TO PENETRATE DOWN THE SOIL
RECHARGING THE SOIL AND THE WATERTABLE
STAGGERED PITTING
CONTOUR TRENCHING & BUNDING
30' x 40' MODEL
5% MODEL
BUND MAINTENANCE
LANDSHAPING
SLOPES
PLAINS
SLOPES >8°
SLOPES 5°×8°
SLOPES 2°×5°
PLAINS 0°×2°
WATER SURPLUS AREA 0°
SUBMERGED SUBSURFACE 40°


STAGGERED PITTING
CONTOUR TRENCHES & BUNDS
40'x30 MODEL
5% MODEL

Differentiated water, moisture and soil conservation

Differentiated water, moisture and soil conservation, Andhra Pradesh, India
The Adivasis communities in the hilly terrain of Andhra Pradesh use centuries-old water harvesting techniques to bridge the dry period between monsoons. The communities facilitate water storage in the topsoil and groundwater recharge by constructing pits, trenches, ponds and stone bunds along the contours of the slopes, both on cultivable and on waste land.

Five different types of water conservation are applied along the hill slopes, each technique being appropriate for a certain slope and position:

- Staggered pitting on very high land: infiltration pits are made, combined with a half circle of stone bunds, on the slope just above a tree.
- Contour trenches on slopes > 8%: trenches are dug on parallel contour lines and contour bunds are built with natural stones and mud. Suitable crops are cultivated between the bunds. Trees are planted at regular intervals using the staggered pitting method.
- 30’ x 40’ model on slopes between 5% and 8%: the area is divided into small rectangular plots of 30 x 40 feet size, with a conservation pit in the lowermost corner to collect rainwater. These sink pits also collect the fertile top layer of eroded soil from the surrounding area. The excavated earth is used to prepare bunds along the plot.
- 5% model on slopes between 2.5% and 5%: a pit is excavated in the lowest corner covering 5% of each plot. A bund arrests the runoff of the first rainwater so that the plot can be saturated. Water enters the pit through seepage, conserving moisture. Paddy is cultivated in these plots.
- Percolation tanks on the foot of the hill catch the remaining water from the slopes. These tanks have an overflow to lead the surplus water to the fields via irrigation channels.

This combined approach increases the general level of sub-surface moisture, recharges groundwater (that supplies drinking water to wells), prevents soil erosion, and improves soil productivity and crop cultivation. Together with appropriate cropping combinations and an increased vegetation cover, 70% of the rainwater can be retained.

Applying conditions:
On hilly terrains in semi arid regions.

Advantages:

- Low costs: local materials and local labour.
- Combination with other community activities (e.g. education, social development).

Educational drawings teaching sustainable water and soil conservation, India (Velugu).


Runoff
Sub-surface flow

Considerations:

- Choice of most appropriate technique in relation to slope.
- Optimal dimensions of pits, trenches and stone bunds.
- Selection of suitable crops and trees.
- Introduction of trees and shrubs that rehabilitate degraded grazing lands and can also be used as fodder.

Costs:

- Material:
  - 1 percolation tank: US$ 1,300
- Labour:
  - Staggered pitting: 1 day / pit (US$ 0.65 per day, including local contribution)
  - Contour trenches: 5.7 day / m
  - Stone bunding: US$ 44 / acre (US$ 0.01 / m^2)
  - 30'x40' and 5% system: 1.25 day / m^3 excavation

Information:

info@aquaforall.nl

Excavation of a conservation pit, India (photo: Velugu).
Cross section of runoff and sub-surface flow as result of the construction of trenches and bunds.

Contour trenching, Amboseli, Kenya

Contour trenching involves digging trenches along the contours of a hill. The technique is widely applied for erosion control, replenishment of the sub-soil and helps air and water to infiltrate compacted soils, improving soil conditions.

In the drought-prone Amboseli area of South East Kenya, deep and closely spaced trenching is chosen, to force all the overland flow from rainfall to infiltrate into the sub-soil. Trenches of 150 m long, 4 m wide and 1 m deep are dug at 25 m intervals down the slope. These are big enough to capture water from a high intensity storm of 150 mm per day.

Soil from the trenches is spread over the surface, where it creates a fertile top soil. Stone walls are built upstream to filter silt out of the runoff water. In Amboseli, the technique was combined with a downstream pond, used by livestock and wildlife. The first results on a 0.5 km^2 pilot plot show a regeneration of vegetation, re-hydrated soil and better seepage into the pond.

Applying conditions:

- Contour trenching should not be applied on slopes > 10%.
- Location and interspacing is determined by rainfall and upstream overland flow. In conservation areas or pastoral lands, the sides of the trenches are made vertical to avoid trampling. In agricultural areas a trapezium-shaped section is recommended.
- Ploughing is not recommended, as it induces evaporation.
- Trenches can be connected to the wall of a sand dam, increasing infiltration.
- In mountainous terrain, contour trenching can be combined with stone walls, hedges and sand dams to turn the whole basin into a rainwater catchment area and protect against erosion and landslides.

Considerations:

- Attention must be paid to minimising evaporation and related salinisation.
- It is not recommended to apply deep and intensive trenching at a large scale until the conditions for its application and the long-term environmental impact are fully understood. Instead, small-scale pilot studies are recommended. Feedback on this technique would be appreciated.

Costs:

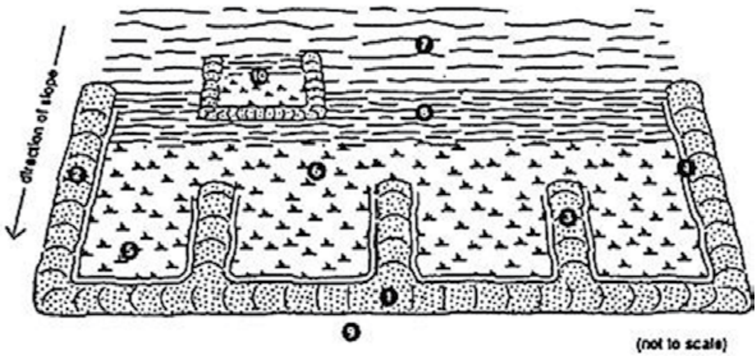
- Material:	US$ 2.6 / m^3 or US$ 4,100 / ha
- Labour:	1.5 m^3 per person per day manual earth movement

Information:

www.westerveld.nu

Contour trenches under construction and measuring contours with hose pipes (photos: WCT).

1. Base contour bund
2. Outer collection arm
3. Inner collection arm
4. Shallow channel
5. Basin
6. Cultivated area
7. External catchment
8. Internal catchment
9. 'Mother' (main structure)
10. 'Child'



Teras, Ilat Ayot, Eastern Sudan

Teras is the name of a plot which is 'bunded' on three sides. The fourth side is left open to capture runoff from an adjacent, slightly elevated catchment. The bunds consist of small stone or earthen walls, constructed along the plot contour to obstruct overland water flow on hill slopes. These bunds reduce flow velocity, so that water percolates into the soil behind them, increasing soil moisture and recharging groundwater. Bunds also trap washed sediment, and locally prevent erosion and land degradation. A shallow channel on the inside of the bunds is made to let the water run along. Excess water drains along the tips of the outer arms. These spillways may improve the efficiency and reduce maintenance costs of teras. The base bund can be 50-300 m long, while the arms are usually 20-100 m long.

Teras show higher crop returns in dryer years and allow farmers to diversify income sources in normal years. In West Africa the technology is widely used in valley bottoms.

Applying conditions:

- Foothill areas with high intensity and short duration rainfall, between 150 and 400 mm annually.
- Catchments are typically 2 to 3 times the size of the cultivated area in (semi-) arid regions.
- Bunds are built by hand from local alluvial and colluvial material. In dryer areas, brush-wood is erected to capture windblown sand and dust, to raise the height of the bunds.
- Bunds are usually 0.5 m high and 2 m deep at the base, but these dimensions can greatly vary depending on both the slope and expected runoff in the area.
- The base bund approximately follows the contour line and holds the runoff; the two outer arms trap water and act as conveyance structures to direct water. Sometimes, shorter inner arms are added to improve the spreading of captured runoff.

Considerations:

Low infiltration capacities increase runoff in teras catchment areas.

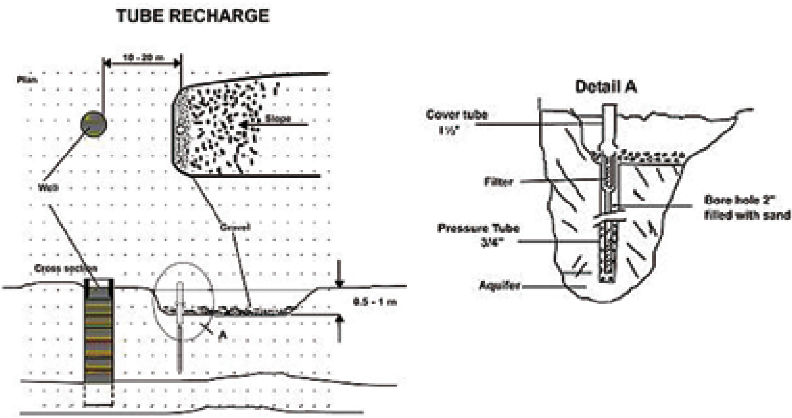
Costs:

Labour for construction:	6-16 days per hectare
Annual maintenance:	3-18 days per hectare

Information:

www.unep.or.jp

Sketch Teras (van Dijk), **Construction of stone bunds to obstruct overland water flow on hill slopes, India** (photo: Velugu).


TUBE RECHARGE
10 - 20 m
Plan
Slope
Well
Gravel
Cross section
0.5 - 1 m
A
Detail A
Cover tube 1½"
Filter
Bore hole 2" filled with sand
Pressure Tube 3/4"
Aquifer

Tube recharge of groundwater, Ghana

Tube recharge is a low-cost technology that combines manually drilled holes with drainage tubes that pass through the compacted topsoil layer. Rainwater that normally evaporates or runs off to rivers now penetrates into the ground and replenishes aquifers.

The tube recharge system consists of a plastic hose or PVC tube with a diameter of 20-30 mm. These tubes are placed in manually drilled holes, upstream of a production well and at a location where water collects naturally or in an artificially constructed pond. When the pond is filled up after rain, some hours have to be waited before opening the drainage tube, in order to settle the dirt. Before the water enters into the tube, it is filtered by a filter tube. The length of the tubes is 5 to 10 m, depending on the size of the compact topsoil. They do not go into the aquifer itself.

Each rain event will recharge the aquifer with about 2-10 m^3, depending on the size of the pond. The capacity and flow patterns of the groundwater determine the extent to which recharged water can be pumped up during the dry season.

Applying conditions:

The local geological situation dictates specific requirements, costs and time: if there are no stones or boulders, a 10 m hole can be made in one day or less with a so-called ‘step auger’.

Considerations:

- Maintenance consists of unclogging the drainage tube by swabbing: moving a stick with a cloth up and down the drainage hole.
- Prior to placing the recharge tubes, testing is needed to determine the best sizes of tube, depth, maximum capacity of recharge, etc.
- Before tube recharge systems are applied on a larger scale, their effectiveness in a given context should be further investigated by means of smaller pilot systems.

Costs:

- Total cost per system (drilling costs, tubes, labour): US$ 5-30
- Step auger or Baptist drill set for holes up to 12 m (can be used for many holes): US$ 75

If the holes are drilled by the families themselves, labour costs can be minimised.

Information:

www.practicafoundation.nl www.gaia-movement.org

Tube recharge as applied in Ghana and Zimbabwe (H. Holtslag, DAPP Zimbabwe).

Websites

Further **information** about water harvesting techniques and success factors can be found through:

Acacia institute	www.acaciainstitute.nl
AFPRO	www.afpro.org
Agromisa	www.agromisa.org
Amref	www.amref.nl
Aqua for All	www.aquaforall.nl
Asal	www.waterforaridland.com
CTA	www.cta.int
ETC	www.etc-international.org
Fakt	www.fakt-consult.de
FAO	www.fao.org/ag/agL/aglw/wharv.htm
Financing for Water	www.financingwaterforall.org
Gaia Movement	www.gaia-movement.org
GCSAR	www.gcsar.gov.sy
IAH MAR	www.iah.org
ICARDA	www.icarda.org
ICCO	www.icco.nl
ICIMOD	www.icimod.org
IGRAC	www.igrac.nl
IIRR	www.iirr.org
Ileia	www.ileia.nl
IRC	www.irc.nl
IRCSA	www.ircsa.org
IRHA	www.irha-h2o.org
IWMI	www.iwmi.cgiar.org
Metameta	www.metameta.nl
NWP	www.nwp.nl
OIEau	www.oieau.fr
Plan Nederland	www.plannederland.nl
Practica foundation	www.practicafoundation.nl
Practical Action (ITDG)	www.practicalaction.org
Prolinnova	www.prolinnova.net
RAIN foundation	www.rainfoundation.org
Rainwaterharvesting	www.rainwaterharvesting.org
Searnet	www.searnet.org
Simavi	www.simavi.org

Skat	www.skat.ch
SNV	www.snvworld.org
Stichting Brazilië Zending	www.braziliezending.nl
UN water	www.unwater.org
UNCDF	www.uncdf.org
UNEP	www.unep.org
WASTE	www.waste.nl
WCA infoNET	www.wca-infonet.org
WCT	www.westerveld.nu

Harvesting water with wind rope pump, Mozambique (photo: Arrakis, Gaia).

Some useful literature:

Agrodok 11, Erosion control in the tropics, Agromisa and CTA, 76 pages, 1986, ISBN 90 72746 07 4 5

Agrodok 13, Water harvesting and soil moisture retention, Agromisa, 95 pages, 2003, ISBN 90-770773-40-X

Agrodok 27, Establishing and managing water points for village livestock, Agromisa, 75 pages, 2000, ISBN 90-77073-64-7

Agrodok 43, Rainwater harvesting for domestic use, Agromisa and CTA, 84 pages, 2006, ISBN 90-8573-053-8

Catchment and Storage of Rainwater, C. Pieck, Technical handbook, 51 pages, 1985, ISBN 90- 70857-03-0

Cosechar Lluvia, Guía de implementación y uso de lagunas - atajados, M. Verweij, Coraca Aiquile Bolivia and SNV, 91 pages, 2001, ISBN 99905-0-098-3

Groundwater Dams for Small-scale Water Supply, Ake Nilsson, IT Publications, 1988, ISBN 1 85339 050 X

Management of Aquifer Recharge and Subsurface Storage, Netherlands National Committee-International Association of Hydrogeologists (NNC-IAH), Publication No. 4, Booklet, 98 pages, 2003, ISBN 90-808258-1-6

Participatory Groundwater Management CD, MetaMeta, www.metameta.nl

Rain Catchment and Water Supply in Rural Africa: A Manual, Erik Nissen-Petersen, Technical manual, 81 pages, 1982, ISBN 0-340-284293

Rainwater Harvesting, The collection of rainfall and runoff in rural areas, Arnold Pacey with Adrian Cullis, Stichting Tool, The Netherlands, Book, 200 pages, 1986, ISBN 0946688222

Sand Rivers, A manual on site survey, design, construction and maintenance of seven types of water structures in riverbeds, RELMA, Erik Nissen-Petersen, Technical handbook no. 23, Technical manual, 57 pages, 2000, ISBN 9966-896-53-8

Sourcebook of Alternative Technologies for Freshwater Augmentation in Africa, UNEP / International Environmental Technology Centre, Technical publications series 8a, 173 pages, 1999, ISBN 92-807-1508-9

Technical factsheet surface runoff water harvesting, Practical Action, www.practicalaction.org/practicalanswers

The Rainwater Harvesting CD, Hans Hartung, HansFHartung@aol.com, www.margraf-publishers.net, 2002, ISBN 3-8236-1384-7

Water from Small Dams, A handbook for technicians, farmers and others on site investigations, designs, cost estimates, construction and maintenance of small earth dams, ASAL, Erik Nissen-Petersen, www.waterforaridland.com

Terminology used in this booklet:	
Aquifer	Saturated underground body, from which the water can be extracted by a well.
Bunds	A small embankment or dike to stop or hold water.
Catchment	Area that contributes surface water to an intake/outflow point.
Discharge	Volume of water transported (in a river / stream) in a certain amount of time.
Grey water	Household wastewater without any input of human and / or animal excreta.
Permeability	Capacity of the soil for transmitting water.
Runoff	Water from rain, snowmelt or other sources that flows over land surfaces or in streams and rivers. Before reaching a channel it is also called overland flow.
Salinisation	Net increase in salt concentration.
Sedimentation	The process of depositing soil or sediment.
Waste water	All types of domestic waste water (sewage, grey water), commercial and industrial effluent as well as storm water runoff.
Watershed	Surface area in which all the (surface) water drains (downhill) to a certain water body.

Call for information

Small-scale water harvesting solutions can provide effective solutions to local water shortages worldwide. The techniques in this booklet illustrate the possibilities and potential of water harvesting with low-cost technology.

The dissemination of 'best practices' requires information that is objective, up-to-date and easily accessible for policy makers and local stakeholders. For this reason, the collaborating organisations mentioned in this booklet intend to go on publishing more on smart technologies. Other titles in this series include:

- Smart Water Solutions
- Smart Sanitation Solutions

Technology is regarded as 'smart' if it can be easily implemented and maintained in local conditions and - most of all - is affordable. If you want to share an experience that fits the smart concept, you are invited to contact NWP:
info@nwp.nl (www.nwp.nl)

Children drinking harvested water from water tank, Burkina Faso (photo: RAIN foundation).