Rooftop Rainwater Harvesting System with Ferro-cement Jars

Nepal – आकाशे पानी संकलन प्रणाली

Rooftop rainwater harvesting system with ferro-cement water jars for individual households.

The vast majority of the rural drinking water schemes in Nepal are gravity flow water supply schemes (QT NEP 40). However, in some cases, there is no feasible way to provide year-round access to safe water sources with gravity systems. This is the challenge in elevated and scattered settlements in hilly areas, where the technical and financial feasibility of gravity supply schemes is challenged by topography, as well as isolated individual households. By the same token, insufficient (seasonal) water yield or compromised water quality of accessible surface and ground water sources may render gravity supply schemes less viable. In these settings, rainwater harvesting systems can complement or temporarily replace other water sources.

Accordingly, the primary targeted group of the technology at hand are financially and socially deprived communities, living mostly from subsistence farming in areas of the Nepal mid-hills, where gravity schemes are deemed unfeasible. While average annual precipitation in this region amounts to about 1,600 mm, it features high inter-annual variability, including a pronounced dry season. As a result, many water sources, especially in higher elevated regions along ridgelines, dry up substantially in the dry summer months. In contrast, during the monsoon season, there is a risk of deterioration of spring water quality.

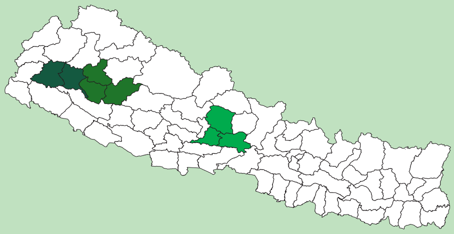
Roof rainwater harvesting systems, rather than representing an autarkic source of water supply, supplement existing surface and groundwater sources. They thereby reduce the need to fetch water from remote springs and help to alleviate temporal or spatial water scarcity. More specifically, they are designed toward bridging the peak dry season by providing enough storage capacity for a family of six to meet their very basic needs. The harvested water is mainly used as drinking water, but also serves other domestic needs. The employed design package aims at balancing long-term functionality with cost-efficient materials:

- **Catchment area:** Corrugated galvanized iron (CGI) sheets with a minimal surface area of 15 m^2 serve as catchment areas. CGI ensures minimal collection losses and remains corrosion-free over long time periods.
- **Conveyance system:** HDPE pipes (roof gutter and downpipes) collect and transport the roof water to the storage tank.
- **First flush diverter:** An extra HDPE pipe is installed between the roof gutter and the storage jar and prevents the initial batch of collected and presumably polluted roof rainwater from entering the tank during precipitation events.
- **Reservoir tank:** Ferro-cement jars with a volume of 6.5 m^3 serve as storage facilities. Ferro-cement represents an economic alternative to storage tanks made of block work, reinforced concrete, or masonry. Given proper maintenance, the jars reach operational lifetimes of more than 20 years. In this configuration, the average supply of one jar is 55 l per day. If only used for the peak dry period (March–May), the stored volume allows for 220 l per day.

During the implementation process, one to two rainwater harvesting workers ("mistri" in Nepali) are capacitated in each scheme to support construction and carrying out maintenance works later on. The sturdy design of the ferro-cement jars results in simplified operation and very low O&M costs. Combined with enhanced feelings of ownership (jars are the personal property of the respective households) it supports the system's longevity. The implementation of RWH systems is usually combined with hygiene and sanitation awareness promotion, as well as technical support for the construction of toilets, changs, and garbage pits (see QA NEP 42).

Left: An installed household rainwater harvesting system in Dailekh (WARM-P)

Right: Construction of rainwater jars where capacitated service providers and the beneficiaries join forces (WARM-P)



Location: Eight districts in the Western, Mid-Western, and Far-Western Development Regions of Nepal

Technology area: per scheme: 1–10 km^2

Conservation measure(s): Structural

Land use type: Settlements

Climate: Humid subtropical

WOCAT database reference: QT NEP 46

Related approach: QA NEP 36

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Comments: Rooftop rainwater harvesting systems are part of the water supply measures planned and implemented within the Water Use Master Plan (WUMP) framework for poor communities in the rural mid-hills of Nepal.

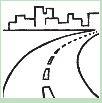
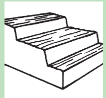
The technology was documented using the WOCAT (www.wocat.org) tool.

HELVETAS Swiss Intercooperation NEPAL ICIMOD WOCAT

Classification

Water use problems

- Growing water demand for both domestic and agricultural use and diminishing or fluctuating water supply due to climate change
- Water sources are intermittent and/or far away; households spend upward of two hours on water fetching

Land use	Climate	Degradation	Conservation measure(s)
			
Settlements, Infrastructure	Humid subtropics	Physical degradation: Local water scarcity	Structural: jar

Stage of intervention	Origin	Level of technical knowledge
Prevention Mitigation/reduction Rehabilitation	Land users' initiative: Experiments/research Externally introduced: 10-50 years ago	Field staff Land user

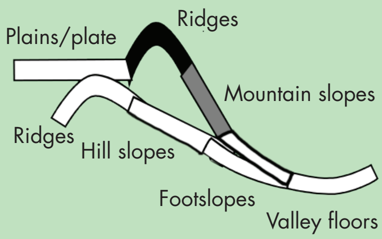
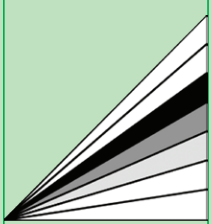
Main causes of local water scarcity

- **Natural causes:** temporary water scarcity during dry season; deterioration of water quality during monsoon period; higher fluctuations in supply due to change in seasonal rainfall patterns; diminishing supply and increasing water demand due to increase in temperature
- **Human-induced causes:** poor water governance; lack of infrastructure; increase in water demand due to to progressively higher living standards and augmented agricultural production

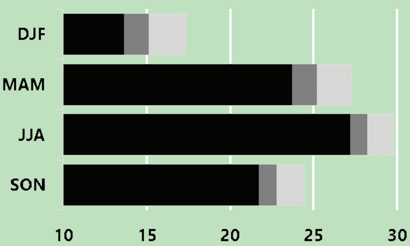
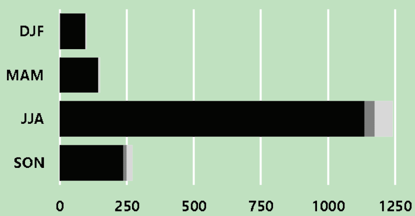
Main technical functions	Secondary technical functions	Legend
• improve water service level (accessibility, quantity, quality, reliability, continuity)	• none	high moderate low insignificant

- Gravity flow or pump systems are often either unfeasible or too costly for elevated and scattered settlements in hilly areas

Natural environment

Average annual rainfall (mm)	Altitude (masl)	Landform	Slope (%)
>4000 3000-4000 2000-3000 1500-2000 1000-1500 750-1000 500-750 250-500 <250	>4000 3000-4000 2500-3000 2000-2500 1500-2000 1000-1500 500-1000 100-500 <100		

Climate change[1]

Temperature (T) in °C	Precipitation (P) in mm	
		– Future **T** increase projected to be most pronounced in dry season – **P** projections still with large uncertainty; **P** predicted to stay constant or slightly decrease in winter (DJF) and increase during the monsoon period (JJA) → Possibility of more frequent winter droughts and summer floods Historical climate: 1976 - 2039 Future climate: 2020 - 2039 Future climate: 2040 - 2059

Tolerant of climatic extremes: temperature increase; wind storms/dust storms; floods; decreasing length of growing period

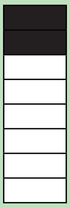
Sensitive to climatic extremes: seasonal rainfall increase/decrease; heavy rainfall events (intensities and amount); droughts/dry spells

If sensitive, what modifications were made/are possible: increase storage volume (e.g., by adding overflow pond)

[1] Historical climate is drawn from local observational records. Future **T** and **P** anomalies are based on the ensemble median of 15 climate models employed in IPCC AR4 representing the SRES B1 emission scenario. Source: World Bank Climate Change Knowledge Portal

Human environment

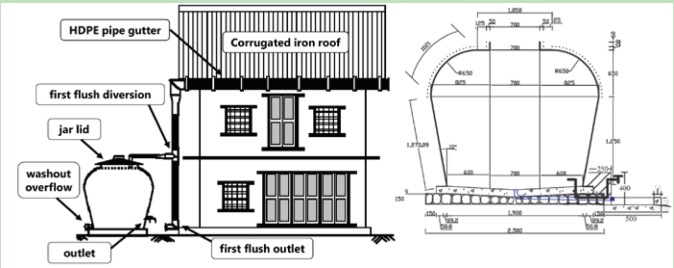
Cropland per household (ha)



<0.5
0.5-1
1-2
2-5
5-15
15-50
50-100
100-500

Land user: individual/household, small-scale land users, disadvantaged land users, men and women
Population density: 120 persons/km²
Annual population growth: 1-2%
Land ownership: individually owned/titled
Land use rights: individual
Water use rights: communal (organised)

Relative level of wealth: very poor and poor, which represent 39% and 27% of population in the area, respectively.
Importance of off-farm income: less than 10% of all income
Access to service and infrastructure: low: health, technical assistance, employment, market, energy, financial services; moderate: education; roads and transport; drinking water supply and sanitation
Market orientation: mainly subsistence (self-supply)



Technical drawing

Left: System overview

Right: Close-up of ferro-cement jar

[scale in mm]

Environment

Establishment activities

Provided all materials are available, construction is completed in about three to four weeks.

1. Selection of suitable site; site clearance
2. Stone soling (15 cm) with sand packing in a circular area of 2.5 m diameter.
3. Prepare and bend the steel rod for the base plate.
4. Construct the concrete base plate (10 cm; cement to sand-to-aggregate ratio of 1:1.5:3) while placing proper fittings for the washout overflow and the outlet. Finish with cement curing of base.
5. Bend reinforcement bars (Ø 8mm); attach them to the base plate and the circular rod on top. Form the main mould with the HDPE 32mm 6kg/cm² pipes.
6. Adjust and fit in the lip mould.
7. Wrap chicken wire mesh over the mould and tie with thin wire.
8. Apply a coat of cement sand on the outer surface (2 cm; cement-to-sand ratio of 1:3). Cover with plastic sheets to retain plastering moisture while curing.
9. Apply second coat of plastering (1.25 cm; cement-to-sand ratio of 1:3), followed by a curing period of at least five days while covering the cement with a damp cloth.
10. Meanwhile, carry out gutter and pipe fitting; including the flush pipe.
11. Remove shuttering, clean the inner side, and apply inner plastering (2 cm; cement-to-sand ratio of 1:3).
12. Cover the jar with damp jute bag to allow for cement curing for up to 14 days.
13. Remove the curing jute, clean the jar interior, and apply a white cement paitning on the outside.

Typical establishment inputs and costs per jar (2014)

Inputs	Costs (US$)[1]	% met by users
Skilled Labour (19 person days)	100	0
Unskilled Labour (24 person days)	85	100
Tools (137 USD per Toolset useable for up to 100 jars)	1	0
Construction Materials		
• Cement (750 kg)	110	0
• Chicken wire mesh (32 m), plain wire, binding wire	65	0
• Metal jar cover	15	0
• HDPE pipes for gutter and mold	30	0
• GI pipes, fittings and valves	20	0
• Plastic sheet and PVC screen	45	0
• Corrugated iron sheet (roofing)	80	0
• Reinforcement bar (Ø 8mm)	20	0
• Mould, gutter nails, thread cuttings, paint, waterproof compound	10	0
Local Materials (costs reflect unskilled labour effort for collection and portering)		
• Stone (0.94 m³)	10	100
• Sand (1.25 m³)	45	100
• Aggregate (0.5 m³)	15	100
• Bamboo	1	100
Total	**650**	**24**

[1] Exchange rate as per June 2015 USD 1 = NRs 100

Maintenance/recurrent activities

1. Cleaning jar once or twice a year
2. Cleaning the roof by flushing away the dirt after long dry periods
3. Emptying the first flush diverter of contaminated water after rainfall events

Maintenance/recurrent inputs and costs per year (for above pond)

Inputs	Costs (US$)	% met by users
Labour (5 person days)	18	100%
Total	**148**	**100%**

Implementation Activities, Inputs, and Costs

Remarks: The above cost breakdown is based on the analysis of 400 jars implemented in 12 schemes the period from 2010 to 2014. Costs for portering and road transportation of non-local materials – very much subject to the remoteness of the project site – were omitted. Village Development Committees (VDC) finance the roof CGI sheets, which make up about 10% of the overall costs. Community contribution to the overall costs (including project management and all transportation costs for non-local materials) is typically between 20% and 25%.

Most operation and maintenance activities are carried out by the users themselves. Repair works are taken over by rainwater harvesting mistris ("mistri" is a Nepali word meaning a skilled worker) and are generally paid for by the users on an individual basis. In a few schemes where an O&M fund was introduced, repair works are financed out of the fund, which is managed by the scheme's User Committee.

Assessment

Impacts of the technology			
Production and socioeconomic benefits		**Production and socioeconomic disadvantages**	
+ +	Increased drinking/household water availability (~20 m^3 per year)	–	Loss of land (to accommodate jar)
+ +	Decreased workload; reduced time for water fetching (on average two hours per day per jar)	–	Regular payments to O&M fund
Sociocultural benefits		**Sociocultural disadvantages**	
+ +	Significant reduction of reported incidents of water-borne diseases due to improved water supply		None
+ +	Increased school attendance of children		
Ecological benefits		**Ecological disadvantages**	
+ + +	Improved harvesting/collection of water		None
Off-site benefits		**Off-site disadvantages**	
+	Neighbors may benefit from stored water during dry periods as well		None
Contribution to human well-being/livelihoods			
+ + +	Decreased workload due to reduced time for water fetching: on average two hours per day per household. The saved time is reported to be spent on livestock raising, vegetable cultivation, and household chores.		
+++: high / ++: medium / +: low			

Economic costs and benefits per household (USD)	**Assumptions**
	▪ Saved time: two hours per day per household; assume that half of the saved time is spent on productive activities ▪ Local rate for one person day (eight hours) of unskilled labour: USD 3.5 O&M costs: USD 18 per year (~3% of total construction costs per year) ▪ Discount rate: 10%
Under the above assumptions, the break-even point is reached after 6.5 years. The net present value per HH (for an assumed lifetime of 20 years) is around USD 550 . The scheme has a Benefit/Cost Ratio of 1.7 and an Economic Internal Rate of Return (EIRR) of 21%. While establishment costs are too high for most poor communities to bear by themselves, O&M expenses are generally paid by the users. Economic benefits may increase further if surplus water is stored in irrigation ponds (QT NEP 42) and used for irrigation of vegetables.	

Acceptance/adoption
The implemented water schemes are identified and prioritized based on inclusively planned WUMPs (QA NEP 36). Moreover, representatives of the community take a lead role in the detailed planning and implementation process, resulting in a high acceptance rate of the technology; virtually all households are making use of their water jar. On the other hand, 6.5 m^3 jars are often too costly for communities to adopt without substantial external material support, either by the government (VDC/DDC) or other donors.

Concluding Statements

Strengths and ➔ how to sustain/improve	**Weaknesses and ➔ how to overcome**
The stored water represents enough supply for the whole household to bridge the peak dry season, thus providing temporary independence of other water sources ➔ ensure that the increased household water supply results in improved health outcomes by combining jar construction with hygiene awareness, as well as household water treatment and storage education campaigns	High costs: water jar technology is more expensive than, for example, a gravity supply system (USD ~650 vs. USD ~250 per household), making it too expensive for poor households to afford by themselves, which is reflected in low adoption rates ➔ (i) scale of implementation is crucial to profit from bulk acquisition; (ii) secure additional funding by disseminating and marketing WUMP); (iii) microfinance or governmental subsidy schemes may represent an additional funding source
As women and children are predominantly responsible for water fetching, less dependence on remote water sources reduces their workload and frees up time for other activities. The saved time resulted in higher school attendance and is reported to be spent on productive activities, household chores, child care, and rest ➔ consider how additional (income) opportunities could be seized (e.g., cultivation of vegetables in kitchen garden)	The supplied water can only partially fulfill domestic water demands. Households are thus still dependent on possibly remote, polluted, and/or intermittent ground and surface water sources ➔ (i) preserve/increase yield of existing sources by implementing source conservation and improvement measures); (ii) consider solar lifting schemes to cater to communities where gravity flow systems are not feasible; (iii) increase irrigational water supply by expanding rainwater harvesting with irrigation ponds)
Sturdy and fail-safe structure: 95% of the jars are functional five to ten years after construction, with a potential lifetime of more than 20 years ➔ Ensure adequate maintenance to keep schemes functional over the whole lifespan by fostering local ownership, capacitating local maintenance workers and user committees, and installing an operation and maintenance fund	The quality of the stored water may be compromised if the jar is not operated prudently ➔ Maximize quality of stored water by educating users on operational measures such as first flush diversion, cleaning of roof and gutter after long dry spells, or annual cleaning of the jar. Raise HWTS awareness and promote treatment methods such as SODIS, filtering, or boiling of water.

Key references: SWISS Water & Sanitation NGO Consortium (2013) Beneficiary Assessment of WARM-P, Nepal. Lalitpur, Nepal: WARM-P/HELVETAS;
HELVETAS (2013) The Effectiveness and Outcomes of Approaches to Functionality of Drinking Water and Sanitation Schemes. Lalitpur, Nepal: WARM-P/HELVETAS

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