# Canal Irrigation Systems

## Nepal – कुलो सिंचाई योजना

**Construction and rehabilitation of canal irrigation systems for smallholder farmers in the mid-hills of Nepal.**

The canal-fed irrigation systems presented here are a traditional irrigation technology built and managed by local farmers in Nepal. The canals carry water from small rivers, streams, and rivulets to the cultivable area. In contrast to pond irrigation systems (QT NEP 43, 42), gravity flow canals are usually located in lower and wetter areas of the mid-hills with subtropical climate conditions where landowners with comparatively larger command areas (on average 0.18 ha irrigated area per household) are living. During the rainy summer season, paddy is cultivated for the most part, while wheat is typically grown in the temperate winter.

While the pond irrigation systems are externally introduced in the generally more poor and water-scarce areas further uphill, canal schemes are mostly concerned with the rehabilitation of malfunctioning or non-functioning existing systems in the plains and valley floors. This concerns systems where either the damage exceeds the technical or financial capacity of the community to repair (e.g., extreme topography of channel alignments, intakes on rivers) or where problems in scheme management cannot be settled internally (e.g., water not available for tail end users). Malfunctioning systems often establish a vicious circle, where diminished water availability leads to lower cropping, which in turn results in reduced income and insufficient funds for rehabilitation. Command areas are often expanded while rehabilitating the system for the benefit of more disadvantaged/small farmholders.

The following principles guide the construction/rehabilitation of the canal systems:

- **Minimum source yield:** The tapped water sources should guarantee at least 4,300 liters per Ropani per day (a Ropani is a Nepalese customary unit of measurement and is equivalent to 509 m$^2$) or roughly 85 m$^3$ per day per hectare. For the most part, the programme makes use of perennial water sources located uphill of the scheme. The minimum source yield is determined in the dry pre-monsoon months of April and May.
- **Mean irrigation demand:** Water demand for irrigation is subject to cropping patterns and employed irrigation methods. For the program's standardized design, the average water demand is presumed to be 500 liters per Ropani per day, equivalent to 1 l/m$^2$/d.
- **Peak demand:** Peak demand is assumed to be three times the average demand or 1,500 liters per Rop. and day.
- **Limited canal length:** Management and upkeep efforts increase considerably in systems with large canal networks. Therefore, the maximum total canal length is limited to 5 km per project.

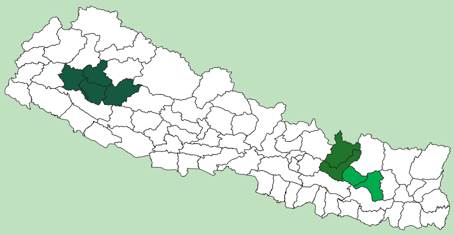
Water sharing policy: As water availability is generally sufficient for the cultivated land in canal systems, the users often adopt policies which allocate water in proportion to the area under cultivation (see also QA NEP 41). By the same token, individual user fees for the operation and maintenance fund are set proportional to the allocated water and – by extension – also to the cultivated land.

While the rehabilitated systems show considerable variation in their salient features and specific components, the program's standardized design guidelines are reflected in the Design Manual for Small Scale Irrigation Schemes published by the Department of Local Infrastructure Development and Agricultural Roads (DoLIDAR). The standardized designs are adapted according to local needs and circumstances, namely local water availability, water requirements of the proposed crops, and agreed-upon operation rules with the farmers.

The rehabilitated irrigation schemes induce a rise in agricultural production in general and a distinct raise in cereal yields in particular, translating into a vital improvement in food sufficiency. In some places, staple cereals are partly replaced by vegetables, contributing to a healthier diet. Depending on market access, the increased production also allows farmers to sell part of the harvest and augment their income.

**Left:** Intake works for the Thanichaur canal irrigation scheme, Chhinchu VDC in the Surkhet district (LILI)

**Right:** Canal construction in seepage area for the Ringrinkhola scheme in the Ramechhap district (LILI)



**Location:** Eight districts in the Central, Eastern, and Mid-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 40, 41

**Related approach:** QA NEP 41 and QA NEP 36

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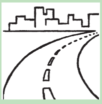
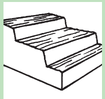
**Date:** June 2015

**Comments:** The canal irrigation systems described here are part of the irrigation measures planned and implemented within the Water Use Master Plan (WUMP) framework for poor communities in the rural mid-hills of Nepal.

## Classification

**Water use problems**

- Growing water demand for both domestic and agricultural use and diminishing or fluctuating water supply due to climate and socioeconomic changes
- Lack of irrigation water and agricultural inputs result in poor agricultural productivity and food insecurity
- Breakdown of irrigation systems: a significant part of existing schemes in Nepal is  not fully functional, indicating a lack of proper management and maintenance

| Land use | Climate | Degradation | Conservation measure(s) |
|---|---|---|---|
|  |  |  |  |
| Settlements, infrastructure | Humid subtropics | Physical degradation: local water scarcity | Structural: canals |

| Stage of intervention | Origin | Level of technical knowledge |
|---|---|---|
| Prevention | Land users' initiative: 100 years ago | Field staff |
| Mitigation/reduction | Experiments/research | Land user |
| Rehabilitation | Externally introduced: | |

**Main causes of local water scarcity**

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

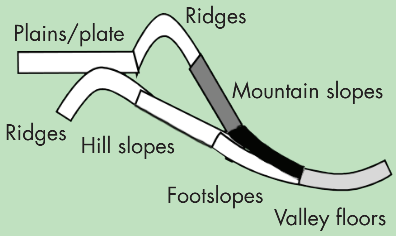
| Main technical functions | Secondary technical functions | Legend |
|---|---|---|
| • improve access to irrigation water | • None | high |
| | | moderate |
| | | low |
| | | insignificant |

## Environment

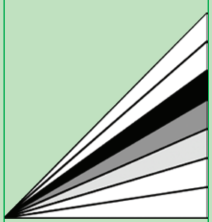
**Natural environment**

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

Landform

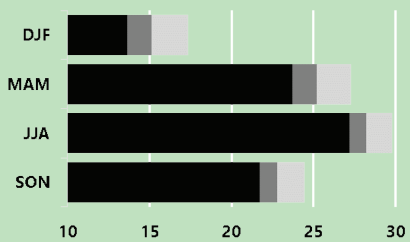



Slope (%)

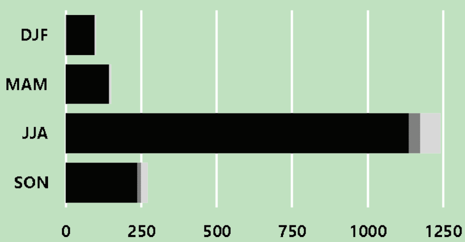



**Climate change**[1]

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 - 2005
Future climate: 2020 - 2039
Future climate: 2040 - 2059

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

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

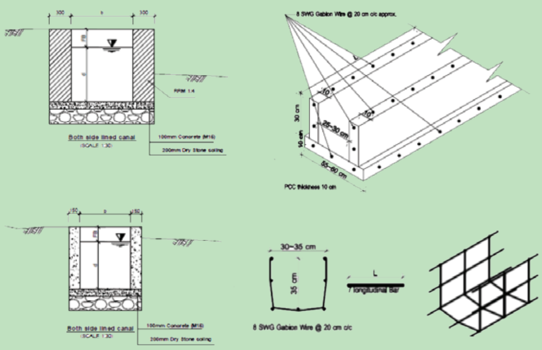
**If sensitive, what modifications were made/are possible:** consider source conservation measures (QT NEP 48)

[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) | | |
|---|---|---|
| | **Land user:** individual/household, small-scale land users, disadvantaged land users, men and women<br>**Population density:** 120 persons/km$^2$<br>**Annual population growth:** 1-2%<br>**Land ownership:** individually owned/titled<br>**Land use rights:** individual<br>**Water use rights:** communal (organised) | **Relative level of wealth:** very poor and poor, which represent 39% and 27% of population in the area, respectively.<br>**Importance of off-farm income:** less than 10% of all income<br>**Access to service and infrastructure:** low: health, technical assistance, employment, market, energy, financial services; moderate: education, roads & transport, drinking water supply and sanitation<br>**Market orientation:** mainly subsistence (self-supply) |

Cropland per household (ha): <0.5, 0.5-1, 1-2, 2-5, 5-15, 15-50, 50-100




Source: Design Manual for Small-Scale Irrigation Schemes published by DoLIDAR

**Technical drawing**
Canals for small-scale hill irrigation schemes.

**Upper left:** Typical cross-section of traditional masonry lined canals as implemented by the programme in 2006-2007. Challenges with the masonry lined systems included:

i) Thick walls (30 cm) result in a comparatively large width of whole structure (> 1m): requires more space and may create challenges for land acquisition
ii) Need for advanced professional skills, as tiling of wall requires very precise work
iii) Structure is more prone to cracks and leakage

**Upper right and bottom row:** Typical cross-section and sketches of concrete canals with minimal nominal reinforcement as implemented by the programme from 2008 onwards. Gabion wire is an economical and simple-to-transport reinforcement option. This canal structure features thinner walls (10-15 cm), requires less delicate construction works, and is more resilient to cracks and leakage.

## Implementation Activities, Inputs, and Costs

**Establishment activities**
Establishment is usually carried out in the dry period under the supervision of local service providers using construction tools, which include measuring tape, spade, shovel, knife, hoe, hammer, trowel, and pan.

1. Site clearance and fixing of canal bed
2. Dry stone soiling (15 cm) of canal bed
3. 7.5 cm layer of lean plain cement concrete (1:3:6) over the stone soiling
4. 10 cm of reinforced cement concrete (1:2:4) at bed and sidewall. Eight Gauge GI wire is used as nominal reinforcement: seven bars in longitudinal direction along the canal alignment (see technical drawing above), which are tied vertically at 20 cm c/c spacing
5. Allow for canal outlets at appropriate locations
6. Fill and compact sides of canal with soil
7. Provide necessary auxiliary and protection works, e.g., retaining walls, gabion walls, cover slab, foot path along the canal alignment

**Typical establishment inputs and costs for 100 m length of a concrete canal with minimal nominal reinforcement**

| Inputs | Costs (US$)[1] | % met by users |
|---|---|---|
| Skilled Labour (16 person days) | 90 | 0 |
| Unskilled Labour (80 person days) | 280 | 15 |
| Construction Materials | | |
| Cement (4,500 kg) | 700 | 0 |
| 8 Gauge GI wire (1,400 m) | 150 | 0 |
| Miscellaneous (nails, wood for form work) | 100 | 0 |
| Local Materials (costs reflect unskilled labour effort for collection and portering) | | |
| Sand (7 m$^3$) | 270 | 25 |
| Aggregate (14 m$^3$) | 350 | 75 |
| **Total** | **1,940** | **19** |

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

**Maintenance/recurrent activities**

1. Monitoring of structures (intakes, bridges, culverts, drop structures; regulating structures, outlets, retaining walls) by walking along the canal network
2. Minor repair and maintenance works

**Maintenance/recurrent inputs and costs per household per year**

| Inputs | Costs (US$) | % met by users |
|---|---|---|
| Labour and equipment | 7.5 | 100% |
| **Total** | **7.5** | **100%** |

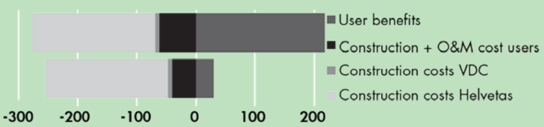
**Remarks:** The above cost breakdown is based on design cost estimates for the period from 2010 to 2014. Costs for portering and road transportation of non-local materials – very much subject to the remoteness of the project site – as well as project management costs were omitted. If feasible, non-local construction materials are procured by the community and paid by the programme. Village Development Committees (VDC) contribute on average about 3% to the overall costs. Community contribution to the overall costs (including project management and all transportation costs for non-local materials) is typically between 10% and 20%. This includes collection and portering of local materials (except sand), as well as unskilled labour work for trench digging, excavation, and construction supporting works. The programme reimburses the unskilled labour required for the construction of the intake structures and the idle length of the main canal. Total average investment costs per scheme amount to about USD 15,000.

In each scheme, a paid caretaker carries out the operation and maintenance activities. The O&M activities are financed out of the scheme's O&M fund, which is managed by the scheme's User Committee (see QA NEP 41). During scheme construction, cash equivalent to 3% of the scheme's total cost is raised for the O&M fund. Thereafter, users contribute with cash and food grain on a monthly basis to pay for the caretaker's salary and finance minor O&M works. Individual cash contributions range from USD 0.10 to 0.25 per Ropani per month. The individual user fees are proportional to the allocated water (and thus to the cultivated land).

## Assessment

| Impacts of the technology | | | |
|---|---|---|---|
| **Production and socioeconomic benefits** | | **Production and socioeconomic disadvantages** | |
| + + + | Increased irrigation water availability, enabling increased agricultural productivity and diversified crop patterns | | Regular payments to O&M fund |
| + + | Given established market access, surplus production can be sold to increase household income | | |
| **Sociocultural benefits** | | **Sociocultural disadvantages** | |
| + + | Improved food security/self-sufficiency, more nutritious diet | | None |
| + + | Strengthened community spirit and fewer quarrels over water due to settled water distribution agreements | | |
| **Ecological benefits** | | **Ecological disadvantages** | |
| + + | Increased soil moisture | | None |
| **Off-site benefits** | | **Off-site disadvantages** | |
| + | Reduced risk of downstream flooding | | Reduced water availability further downstream |
| **Contribution to human well-being/livelihoods** | | | |
| + + | Increased production and greater variety of crops help people to increase food sufficiency. Vegetables contribute to a healthier diet. | | |
| +++: high / ++: medium / +: low | | | |

**Discounted economic costs and benefits per household (USD)**




**Assumptions**

- **Average scheme cost per HH:** USD 250
- **Net average incremental benefit per ha and year:** USD 370. Assume benefit will be 50% in first year and 100% from second year onward
- **Average command area per HH:** 0.18 ha
- **Scheme life:** 10 years
- **O&M costs per HH:** USD 7.5 per year
- **Discount rate:** 10%

Under the above assumptions, the break-even point is reached after seven years. The net present value per HH (for an assumed lifetime of 10 years) is USD 76. The scheme has a Benefit/Cost Ratio of 1.26 and an Economic Internal Rate of Return (EIRR) of about 16%.

**Acceptance/adoption**

Canal-fed systems are traditional irrigation schemes built and operated by farmers, with some of the schemes being more than 100 years old. As such, acceptance of the rehabilitated systems was never an issue. More notably, the newly introduced water allocation mechanisms, which allot water in proportion to the area of cultivated land, are well adopted by most communities.

## Concluding Statements

| Strengths and ➔ how to sustain/improve | Weaknesses and ➔ how to overcome |
|---|---|
| The irrigation schemes can help the farmers in increasing their agricultural production and to cultivate a greater variety of crops ➔ support partial shift from cereals to high value but low water-demanding crops by linking farmers to agricultural service providers and develop their capacity to devise suitable post-construction cropping patterns and irrigation schedules | Due to failing O&M mechanisms, some schemes become partly or fully dysfunctional much ahead of their designed operational lifetime 41 ➔ ensure post-construction support and mentoring for the first couple of years 41, link canal systems to VDC/DDCs for long-term support |
| Concrete canals with minimal nominal reinforcement require less space (and thus ease land acquisition) and are more robust than traditional masonry-lined canals: 98% of the schemes are fully (87%) or partly (11%) functional three years after construction ➔ strengthen institutional mechanisms related to O&M and ensure that they remain active throughout the projected lifetime of each scheme 41 | Maintenance and repair works may require substantial labour input, especially in delicate surroundings or complex structures (extreme topography of channel alignments, intakes on rivers) ➔ emphasize feelings of shared ownership during scheme rehabilitation; mutually establish O&M obligations in tailor-made water use policies |
| As crop patterns get more diverse, surplus cash crops and vegetables may be sold to increase the household income ➔ coordinate with other programs to help establish market access in remote regions; support collection and storing centers or processing facilities for vegetables | Conflicts may emerge when tails users receive less water than originally allotted due to diminishing water sources ➔ capacitate local service providers to help review and adapt water-sharing policies during follow-up visits |
| Gravity flow canal schemes are traditional systems. Farmers are familiar with these schemes and have experience in operation and maintenance ➔ build technical capacity of local service providers to support major repair works, which are beyond the communities' abilities | |

**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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