# Construction of a Water Harvesting Tank - Experience from Kubinde, in the Jhikhu Khola Watershed, Nepal

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**Abstract**

Rapid growth of population in the Jhikhu Khola watershed (JKW) has been accompanied by an increasing emphasis on a cash economy as farmers focus on vegetables for the market of Kathmandu, just 90 minutes drive away. This has resulted in considerably intensified crop rotations to meet the increasing food demand at home, expanding family aspirations, and the growing need for cash to cover household expenditure. It has also led to an increased need for water in winter to irrigate the new cash crops. The available water is actually becoming less, however, as winter water is often diverted causing small feeder streams to dry up, and the ground water table is dropping as a result of increased use of pumps. Thus there is an increasing need to store monsoon water for winter production and to reconsider appropriate soil moisture conservation practices.

PARDYP team members learnt much about micro water storage tanks and underground cisterns during a visit to China. As a result a trial tank was constructed at Kubinde in the JKW. Early tests in the spring of 1999 displayed both the potential and the drawbacks. Crop trials with water stored from the monsoon season will commence in October 1999. The success of this pilot project depends upon the interested involvement of the farmers. The question remains whether even a simplified version of this tank can be afforded by the poorest farmers. Much rests on the outcome of the crop trials and the potential to organise credit facilities.

## Introduction

This paper describes the results of activities undertaken in the Jhikhu Khola watershed (JKW), which lies 45 km east of Kathmandu in Kabre Palanchowk District. The JKW has a rapidly growing population and there is an increasing emphasis on the cash economy as farmers produce vegetables for the market of Kathmandu, just 90 minutes drive from the watershed. These factors have resulted in an intensified crop rotation to meet increasing food demand at home, expanding family aspirations, the growing need for cash to cover household expenditure, and the desire to make the most of the cash income opportunities in the Kathmandu markets.

Only ten to fifteen years ago, farmers in the JKW grew wheat or left their land fallow during the winter, thus water storage was not a pressing need for the dry winter months. Furthermore, most of the streams carried water all year round.

The scenario has changed dramatically in recent years. Valley floor farms are cultivated around the year, and production of high value winter cash crops has become the norm not the exception. The traditionally rainfed valley-side farms are also used for winter cultivation wherever water is available. Available winter water is now diverted and used for irrigation wherever possible, with the result that small winter feeder streams, previously providing a low flow supply, are now dry. In addition, a significant number of farmers have now invested in either diesel or kerosene water pumps, with the result that the ground water table in the watershed is under threat.

, The prevalent dry winter conditions, the possibility that the erratic nature of the winter rains will intensify as a result of climate change, and the steady increase in the demand for winter irrigation, all mean that storing monsoon water for winter production is becoming a pressing need. A fresh look at appropriate soil moisture conservation practices has also become a priority. The water supply and crop water demand situation is most acute on the south facing slopes where acute winter water shortages are experienced.

PARDYP team members learnt much about micro water storage tanks and underground cisterns during visits to China over the past two years. This knowledge was applied to support experiments in the JKW. A trial tank, a conical underground cistern with a storage capacity of about 10 cu.m was constructed at Kubinde in the JKW. It lies within an area of degraded forest at present being rehabilitated by the community. Surface runoff from the 1,500 sq.m catchment area passes through five de-siltation ditches before it is collected by the underground tank. The tank was filled (overflowed) during one storm event on July 21 1999 (21 mm in 24 hour). The stored water will be used on a trial basis by a local farmer to produce cauliflower on 0.2 *ropani* (~100 sq.m.) of rainfed land during the autumn of 1999.

## *Site Description*

Kubinde Gaun, the site of the tank, is reached from the Arniko highway (at Lamidanda) by a 3km partially dirt road through the UN army training camp followed by a 0.5 km walk which crosses the Kubinde Khola (Figure 97). The site is located on a southwest-facing valley-side slope above the cultivated valley floor at an elevation of 890m masl.

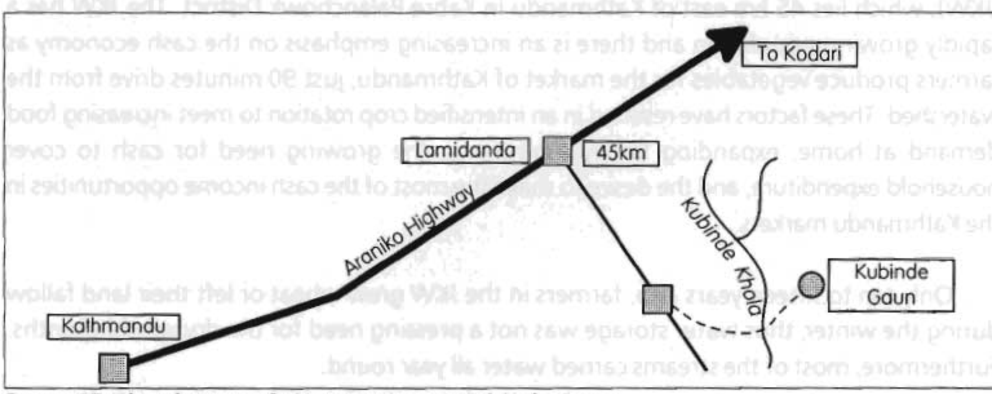


Figure 97: **Sketch Map of Site Location at Kubinde Gaun**

The site area was formally a healthy sal forest (*Shorea robusta*). In the past twenty years the forest suffered severely from overgrazing and felling. The community agreed to close the area to open grazing in 1996 and the forest is slowly recovering.

### *Land Use Practices*

In the valley floor area below the site, rice is the main summer crop and is followed by winter wheat or potato. The fortunate farmers who have access to water, produce tomatoes and bitter gourd in small plots during the winter and spring. Water constraints generally restrict vegetable production to small plots, although all farmers in Kubinde gaun are interested in expanding their areas of vegetable.

Four of the ten households in Kubinde gaun are Thapas, two Kami, two Tamang, and one Thakuri (Table 71). The mean number of persons per household is 5.8.

Table 71: **Ethnic Composition in Kubinde Gaun**

| Ethnic group | No. of Households | Total No. of Persons |
|---|---|---|
| Thapa | 4 | 22 (7+6+4+5) |
| Malla (Thakuri) | 1 | 5 |
| Tamang | 2 | 11 (8+3) |
| Kami | 3 | 20 (4+9+7) |
| Total | 10 | 58 |

## The Purpose of Constructing the Underground Tank

Household water demand has increased significantly over the past two decades, but the year round supply is perceived to have diminished considerably. Records from the Horticulture Station at Panchkhal (Tamaghat) covering 27 years show that there has been no significant

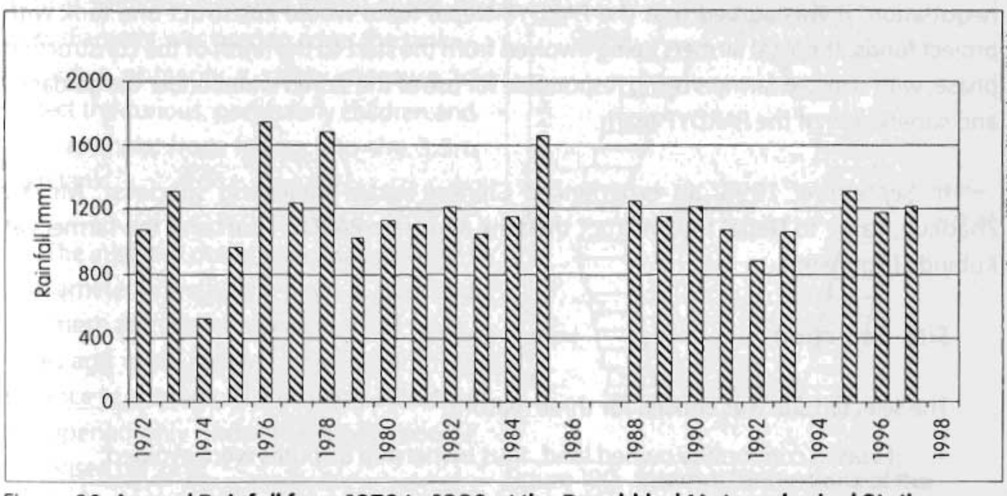


Figure 98: **Annual Rainfall from 1972 to 1998 at the Panchkhal Meteorological Station**

change in the mean annual rainfall over this time (Figure 98). The 27 year mean is 1,184 mm per year. JKW farmers frequently observe that year by year less water is available, however, and complain that this is one of their most critical current problems.

From November onwards, the flow in the Jhikhu Khola and its tributaries decreases sharply, with the result that farmers are now ponding the streams and rivers or digging wells to access the available water. All the farmers interviewed commented that winter flows are decreasing, and blame this on the extensive use of the available winter supplies. For winter crop production, farmers generally have to pump water from January onwards, primarily from pools in the main channel of the Jhikhu Khola. The number of pumps has increased dramatically within the last six years: 50 farmers are now known to own pumps. These are rented out when not in use by the owner.

The Kubinde storage tank was constructed as a response to the farmers' observations to discover whether this type of tank could help solve the problem of winter water.

## The Project Approach

At 1000m elevation in the JKW, winter skies are frequently clear with the result that evaporation rates can be high and open storage tanks are not viable. Thus the Chinese type of underground conical tank was selected for the trial. This type of tank is moderately simple to construct providing there is local access to suitable rock and cement. It can be too expensive for the poorest households, but the tank size is flexible and farmers can select the volume according to their needs and the capital outlay possible.

An approximate site on the south facing slope near Kubinde village was selected as the trial area in May 1998, following discussions with the local farmers. The farmers originally had a mixed reaction; on the one hand they were suspicious about the new concept, on the other they wanted to observe and evaluate the potential of the tank. After protracted negotiation, it was agreed that the PARDYP-Nepal team would construct one tank with project funds, the local farmers being involved from the start to the finish of the construction phase, with selected farmers being responsible for use of the stored water under the guidance and supervision of the PARDYP team.

In September 1998, an experienced Chinese water-harvesting specialist, Mr. Xu Zhaokun, came to Nepal to construct the tank and train PARDYP staff and the farmers at Kubinde (Figure 99).

### *Site Selection*

The selected site was chosen for three reasons:

- it was in community owned land, thus ownership disputes were avoided;

- it lay above the small Kubinde village and an area of agricultural land, thus permitting research and demonstration in terms of utilisation of the stored water for production of cash crops;
- it could provide water for the plantation activities related to forest rehabilitation if needed.

Figure 99: **Mr. Xu Zhaokun Advising the Nepal Team on Construction of the Water Tank**

The site was located at the foot of the degraded forest land that provided the catchment area. The slope of the area varied between 12 and 24 degrees.

Mr. Xu stressed that site stability was of primary concern, and that flat or nearly level red soil terrain and rocky areas were more stable and suitable than colluvial slopes, debris accumulations, fans, scree, or talus deposits. In addition, the storage tank should be as close to the field to be irrigated as possible with a head drop of 2-3m. The Chinese experience is that individually-owned tanks produce the best results, although that was not possible for this demonstration.

*System Design*

The tank was designed to have a capacity of about 10 cu.m. The limit was set by the time available, cost, and local terrain. Following advice from China, the tank was made conical or bottle-shaped, which is optimal for strength and stability. The design is shown in Figure 100. The tank was circular in a horizontal section, but dome-shaped in a vertical section. A round metal sheet of 0.7m diameter was used to cover the tank—this lid is primarily a safety measure to protect the curious, particularly children and small animals, from falling into the 3.5m deep tank.

The inlet and outlet were made of eight cm diameter polyethylene pipes. Galvanized wire mesh at the inlet pipe prevented twigs, leaves and other coarse material from free entrance to the tank. The lid was padlocked and opened only under the supervision of authorised persons.

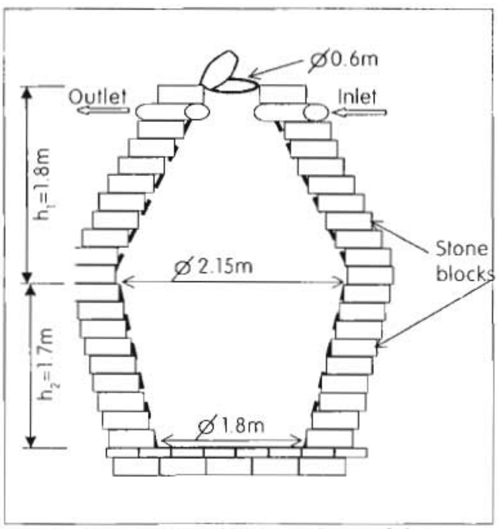


Figure 100: **Internal Dimensions of the Underground Tank**

The runoff passes through five settling ponds before it runs into the tank because the sediment output from this type of degraded red soil area can be as high as 40 t/ ha (Nakarmi & Mathema this volume). One cement mortared siltation pond (1x1x1m) was constructed in front of the tank entrance and a second similar pond four metres upslope. Three temporary ponds (1x1x0.5m) were placed at strategic locations within the runoff channel system (Figure 101).

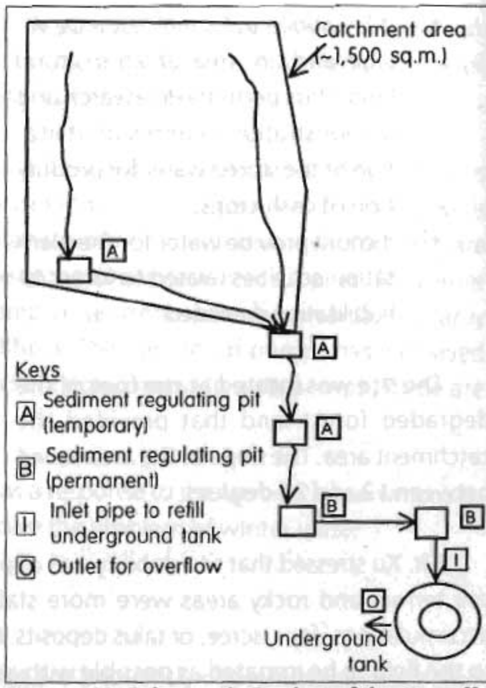

Figure 101: **Schematic Design of the Runoff Harvesting System**

### *Tank Construction*

After the site had been identified, the centre point of the tank was located and marked on the ground. A circle of 0.8m diameter was drawn around the centre, and excavation begun vertically downward. The initial excavation of the first ½ m of red soil below the surface went smoothly, but digging out the underlying micaceous quartzite rock and rubble was time consuming and hard work. Even so, the excavation work was completed in five days by two people (Table 72).

The excavated materials were dumped near the site for later use to fill depressions. The tank walls were constructed with locally available unfaced stone using a wall thickness of generally 20 to 30cm, although in places it reached 45cm as a result of the irregular cavity shape and stone size. The stones were fixed with cement mortar. On Mr. Xu's recommendation, the weathered quartzite was crushed to a fine sand which produced a perfect cement mortar when mixed with the coarse river sand purchased from a close-by watershed. Once the rate of pay was fixed, the female farmers took the initiative to perform stone crushing, and haulage of water, cement, and sand. Almost all the inhabitants of

Table 72: **Schedule of Construction Activities from September 12-21, 1998**

| Activities | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|
| Excavation | x | x | x | x | x | | | | | |
| Stone collection | x | x | x | x | | | | | | |
| Stone crushing | | x | x | x | x | x | x | x | | |
| Wall construction | | | | | x | x | x | x | | |
| Plastering | | | | | | | | x | x | X |
| Fine plastering | | | | | | | | | x | X |
| Sand collection and transport | | | | | x | | x | | x | |
| Cement transport | x | | | | x | | | | | |
| Water collection and transport | | | | | | x | x | x | x | X |
| Siltation ditch construction | | | | | | | | | x | X |
| Diversion canal construction | | | | | | | | | | X |

Kubinde Gaun participated directly or indirectly in the tank construction, although the women were more enthusiastic and active than the men.

According to Mr Xu, it is very important to accurately control the sand/cement mixtures. Wall sections, where strength is a major concern, received a 1:6 ratio of cement to sand (Table 73), which was increased to 1:4 near the tank opening where the walls close in. A similarly strong mixture (1:4 ratio) was used to plaster the walls. The bottom of the tank was sealed with a 10 cm thick cement/sand/gravel mixture (ratio 1:3:6). Finally, a cement slurry was applied over the entire inner tank surface as a pore-sealing material.

Safety of the workers is an important concern in constructions of this sort; the tank was completed without injury—except to the project pick-up which one afternoon had all four tyres flattened by local children.

Table 73: **Proportion of Sand and Cement Used**

| Type of construction | Material | Ratio |
|---|---|---|
| Cement mortar (for stone wall) | Cement and sand | 1:6 (2 river sand+4 stone dust) |
| PCC bottom | Cement, sand, gravel | 1:3:6 |
| Cement mortar (wall near mouth) | Cement and sand | 1:4 |
| Wall plaster | Cement and sand | 1:4 |
| Final plastering (cement slurry) | Cement | 1 |

### *Catchment Layout*

The area of the catchment surface is determined by the equation:

$$A = V / (C^* R)$$

where, A = catchment area ($m^2$)
V = storage capacity of underground tank ($m^3$)
C = estimated runoff coefficient of the area
R = precipitation (m)

In this case, $V = 10\ m^3$, $C = 0.45$, and $R = 15$ mm $= 0.015$ m (precipitation during a medium rainstorm). The equation is thus $A = 10 / (0.45 * 0.015) = 1481.5$ giving a catchment area for the Kubinde tank of 1500 sq.m. The catchment area is theoretically adequate to fill the tank following one medium rainstorm, although in practice this is dependent on the intensity and duration of the rain events and antecedent soil moisture content. The calculations were based on the desire to be able to refill the tank during occasional brief storms in winter if needed, a much smaller catchment area would have sufficed to simply fill the tank during the monsoon period.

The five siltation ponds were constructed towards the bottom of the catchment area. The runoff channels were also lined with dry rock to check further erosion. The schematic layout of the catchment system is shown in Figure 101.

## The Cost of Construction

The expenses incurred are shown in Table 74.

The 10 cu.m tank cost nearly NRs 25000 to build, equivalent to NRs 2.5 per litre capacity. There is considerable potential for reducing this cost, however. Almost 50 per cent of the money was spent on materials—half for cement and half for stone plus sand. Depending upon the site, sand and stone might be available locally at no charge, which would leave the cost of cement only for materials. Similarly, labour charges were also considerable as this was a research project. If labour was provided by a household or community, the costs would again be reduced. Overall, there are strong possibilities for reducing the cost of tanks of this type, especially through effective community participation.

Table 74: **Cost of Construction**

| Item | Amount | | Per Cent of Total |
|---|---|---|---|
| | NRs | US $ | |
| Materials | 12,000 | 175 | 49 |
| Equipment | 1,400 | 20 | 6 |
| Transportation | 1,000 | 15 | 4 |
| Labour | 10,000 | 146 | 41 |
| Total | 24,400 | 356 | 100 |

## First Trials

### *The Traditional Winter Cropping System*

The current traditional production practices for rainfed winter crops provide poor returns. A Thapa family from Kubinde Gaun provided the crop return data shown in Table 75. The choice of winter crops is very restricted because of the lack of water and the family often leave their land fallow. The return on winter cultivation with the normal selection of crops is not attractive and it is not uncommon for the crop to fail because of lack of rain.

Table 75: **Economic Returns from Winter Dryland Cultivation**

| | | | |
|---|---|---|---|
| **Expenditure** | | | |
| Materials | For 6 ropani | Total expenses (NRs) | Expenses per ropani (NRs) |
| Chemical fertiliser | 2 sacks @ 960 | 1920 | 320 |
| Ploughing | 2 Oxen @ 300 | 600 | 100 |
| Labour | 15 man days @ 100 | 1500 | 250 |
| Total | | | 670 |
| **Income** | | | |
| Crop | Yield per ropani | Rate per unit (Nrs) | Total (per ropani) |
| Maize (*Zea mays*) | 2 muri | 500 | 1000 |
| Niger (*Crizotia abyssinia* "mustard") | 4 pathi | 40 | 160 |
| Total income per ropani | | | 1160 |

Note: 1 *ropani* is approx. 500 sq.m; 1 *muri* is approx. 91 litres; 1 *pathi* is is approx. 4.6 litres

### *Preliminary Tests*

The tank was completed in September 1998. As usual for this time of year, no substantial rain fell during the next six months, and there were also no sufficiently large winter events to fill the tank. Preliminary trials were carried out in collaboration with the Institute of Engineering, Tribhuvan University. They started in April 1999 at the end of this long dry spell using a little collected tank water augmented with water laboriously hauled from the valley bottom stream. Three farmers used the water to produce crops of tomato and capsicum, and were introduced to plastic mulching and individual plant watering. The crops took three to four months to reach maturity. The trial was not a great success, but provided some useful data and an idea of the problems to be faced during the trials to be conducted in the autumn of 1999 (Table 76). On-farm participatory trials can be difficult when new technologies and data collection are involved. (In these trials plastic mulching was used, but future trials will test alternatives like grass and straw.)

<u>Estimated Cost/Benefit of Tomato and Capsicum Cultivation at Kubinde</u>

Rough calculations show the following.

- One *ropani* of winter vegetables requires approximately 20,000 l of water over the growing season.
- This means a 20,000 l tank is needed for production on one *ropani* of land. The approximate cost at an appropriate location could be as little as NRs. 15,000 and a maximum of Rs.50,000, based on the costs of the trial tank and present rates.
- If tomato management and yields could be improved, a yield of 800kg/*ropani* should be possible earning a gross sum of approximately NRs.15,000 (net about NRs.13,000, taking into account the costs for fertiliser and plastic for mulching).
- This means that the cost of the 20 000 l tank could be covered in about 2 to 4 years.

Table 76: **Estimated Water Requirement and Yields for Different Crops**

| Trial | Crop | Mulch | Water (no. of times) * | Total water per plant (l) ** | Water (l) per 100 sq.m. | Water (l) per *ropani* | Trial Yield (kg per *ropani*) | Potential Yield*** (kg per *ropani*) | Gross income from trial (NRs.) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Tomato (*Lycopersicum esculantum*) | Yes | 40 | 10 | 4,000 | 20,000 | 443 | 1000-1200 | 8495 |
| 2 | Capsicum (*C. frutescens*) | Yes | 40 | 10 | 4,000 | 20,000 | 250 | 500-800 | 2500 |
| 3 | Tomato (*L. esculantum*) | No | 40 | 10 | 4,000 | 20,000 | 200 | 1000-1200 | 2500 |
| 4 | Capsicum (*C. frutescens*) | No | 40 | 10 | 4,000 | 20,000 | 160 | 500-800 | 1200 |

* 250ml of water were provided on each of 40 occasions direct to the plant
** whether mulched or not, a total of 10 litres of water were provided to each plant during the 3-4 month cropping period
*** potential maximum yield in Nepal

- In years with reasonable winter rains, and under good management, it might be possible to produce two winter vegetable crops a year (if the tank refilled before the second crop was planted), in which case the construction of a water tank becomes a very attractive option.

These rough calculations suggest that there is potentially a real cost benefit from construction of a water tank.

## Crop Water Requirement for the 1999 Trials

Various methods for calculating crop water requirements are described in Arora (1996) including the Blaney-Criddle method, the Hargreaves pan evaporation method, the Penman method, the Thorthwaite method, and the Lowry-Johnson method. Calculations for the trial were made using the Blaney-Criddle method. This empirical formula is based on mean temperatures, daytime hours, and a consumptive use coefficient. Table 77 shows the monthly values to be used in this formula.

The Blaney-Criddle formula quoted by Arora (1996) is

$$C_u = S\, k_i * p_i\, (1.8\, T_i + 32)/40$$

where $k_i$ is empirical seasonal consumptive use coefficient for the growing season
$p_i$ is monthly percentage of daylight hours of the year
$T_i$ is mean monthly temperature

For Kubinde, this formula gives a total water consumption for a crop grown in the autumn of about 204 mm, with a maximum in October (Table 78).

This suggests that the total water requirement under flood or furrow irrigation conditions in a 10 x 10m plot (100 sq.m) would be 100 x 0.204 cu.m or approximately 20 cu.m (20,000l). This is a high requirement, thus the planned PARDYP cropping trial will investigate

Table 77: **Monthly Temperature, Percentage of Daylight Hours, and Consumptive Use Factor for Vegetables**

| Month | Oct | Nov | Dec | Source |
|---|---|---|---|---|
| Mean monthly temperature (°C) ($T_i$) | 22.2 | 17.7 | 13.7 | HMG/N (1990) |
| Monthly percentage of day-time hours (p1) | 8.09 | 7.40 | 7.42 | Arora (1996, Table 20.2, p.711) |
| Monthly consumptive use crop coefficient ($k_i$) | 0.6 | 0.55 | 0.50 | Michael (1978, Table 7.8, p 524) |

Table 78: **Estimated Consumptive Use of Water by a Vegetable Crop (mm)**

| Month | October | November | December | Total |
|---|---|---|---|---|
| Consumptive use of water | 87 | 65 | 52 | 204 |

crop development using plant by plant irrigation with the rows of plants under plastic mulch. Water will be applied to each plant through a hole in the plastic mulch using a watering can—it is estimated that this will save some 66 per cent of calculated water, so that the water requirement would be 6 cu.m (6000l) per 100 sq.m or 30 cu.m per *ropani*.

Horticulturalists at HMG Department of Agriculture suggested that 500 cauliflower plants can be grown in a 100 sq.m plot. The estimated 6000 l of water required would provide one litre of water per plant per week for 12 weeks. The Kubinde tank can provide this even if there is no rain or runoff during the three month crop production period, but if these calculations are correct a tank twice or three times as large would be required to successfully irrigate one *ropani* (500 sq.m) of winter vegetables if there is no rain during the cropping period.

The actual water requirement may be less than the calculations suggest. Badhani (1998) claimed that in Nainital, UP, India, some different vegetables were grown successfully using 15-22 applications of 0.25 litre of water per plant (3.75 to 5.5 l) over the cropping period (of 3 months). Even the higher figure implies the application of only 2,750 litres to 500 plants or 14,000 l per *ropani* if the plants are planted at a density of 500 plants per 100 sq.m.

These estimates range widely, and clearly well managed trials are required to answer the question of crop water requirement in systems where plants are mulched and individually watered. The water requirement has a direct bearing on the cost/benefit analysis of tank construction, so that the planned trials are considered extremely important.

The crop trial with a three-month cauliflower variety is planned for October 1999. Water will be delivered from the tank to the field via a pipe and the participating farmer/s will measure and record the time taken and volume of water applied to each plant on each occasion. Great care will be taken during the application of water to the plants. The capital outlay is high, and the field management operations are time and labour consuming, so that only a good return on the crop will persuade farmers that water storage for winter irrigation is worthwhile.

## Conclusion and Recommendations

An underground water tank with a capacity of 10 cu.m and catchment area of 1500 sq.m was constructed in 10 days in September 1998, at a cost of Rs.25,000 (US$365 equivalent). It was designed to fill during one rainfall event of 15 mm on moist soil.

Five open settling ponds were constructed to trap sediment. An eight-centimetre diameter polyethylene pipe diverts water from the last pond into the tank.

Local farmers were generally sceptical and only partially convinced of the potential economic return accruing from the construction of the tank. Women were more optimistic than the men and carried out most of the labouring work. The PARDYP project bore the cost of the tank construction as a research and demonstration site. Early tests in the spring of 1999 showed both the potential and the drawbacks. Crop trials with water stored from the monsoon season will commence in October 1999.

The success of this pilot project depends heavily upon the involvement and interest of the farmers, and the question remains of whether even a simplified and cheaper version of this tank can be afforded by the poorest farmers. Much rests on the outcome of the crop trials, and later on the potential to organise credit facilities.

The shortage of water faced by farmers in the Jhikhu Khola is considered to be symptomatic of a larger picture that is evolving in the mountains of the region—the need for winter water in order to capitalise on higher market prices. The potential of stored water to assist in raising household incomes and standards of living is unquestioned, and this research trial hopes to answer some of the key questions, for example: can the majority of farmers afford such a tank; how can construction costs be lowered; what is the cost/benefit relationship; and what in-field management technologies are appropriate, affordable and applicable?

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