3 WATER SCARCITY

Background

Water is rapidly becoming one of Nepal's major concerns, with too much water during the monsoon and too little during the dry winter months. In rural areas, the increasing population has increased the problem of water shortage. According to the 1998/99 water demand and supply survey carried out by PARDYP (Merz et al. 2002), 33% of respondents in the Jhikhu Khola watershed and 41% in the Yarsha Khola watershed thought that shortage of water for irrigation was the most important water issue; 27% in the Jhikhu Khola and 37% in the Yarsha Khola thought it was shortage of drinking water; and 17% in the Jhikhu Khola and 9% in the Yarsha Khola identified drinking water quality is the major problem (Figures 13, 14).

The survey asked whether respondents thought that the supply of irrigation water (men) or domestic water (women) had changed over the last 5 and 25 years. In the Jhikhu Khola watershed, 38% of respondents thought that there was less water, 29% indicated no change; 24% did not answer, and 9% thought that there was more water. In the Yarsha Khola watershed, 79% of respondents thought that there had been no change in water supply, 17% that there was less water, 2% that there was more water, and 1% did not answer (Merz et. al. 2002). Furthermore, 60% of Jhikhu Khola respondents perceived their area as dry and 14% as very dry.

Overall, the supply of irrigation water is perceived to have decreased over the last 5-25 years, as has the supply of drinking water, if not as dramatically. Drying up of rivers, lack

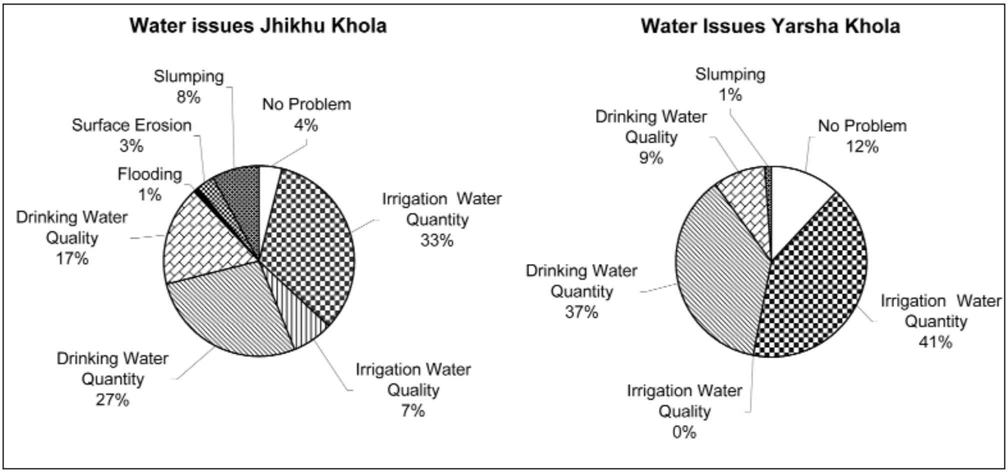

Figure 13: Water-related issues Source: Merz et al. 2002

3 – Water Scarcity

Figure 14: Water scarcity in the watershed

of water for irrigation, and long queues at the public water sources underline the view that water is a scarce resource.

The question is whether the increasing water scarcity perceived by farmers is the result of increased demand due to increasing population and intensification of agriculture, or of reduced supply due to climate change or others.

Water Demand and Supply

The population in the Jhikhu Khola watershed has been growing faster than the national population (see Table 1), and population density has increased significantly (Figure 15). A growing population leads to increasing water demand for both consumption (drinking) and production (irrigation).

Demand for household consumption

The water demand and supply survey showed that people in the Jhikhu Khola watershed used 23 litres per day per person for domestic purposes, half the guideline of 45 litres per day for rural water supply schemes (RWSSSP 1994). The estimated total water demand almost doubled between 1996 and 2006 (Table 9).

With increasing awareness of sanitation issues, domestic water demand may increase even more in the future. The 2004/05 Jhikhu Khola watershed livelihood survey showed that 46% of the residents use modern toilets, both flush and non-flush types. This number has increased significantly in the last few years.

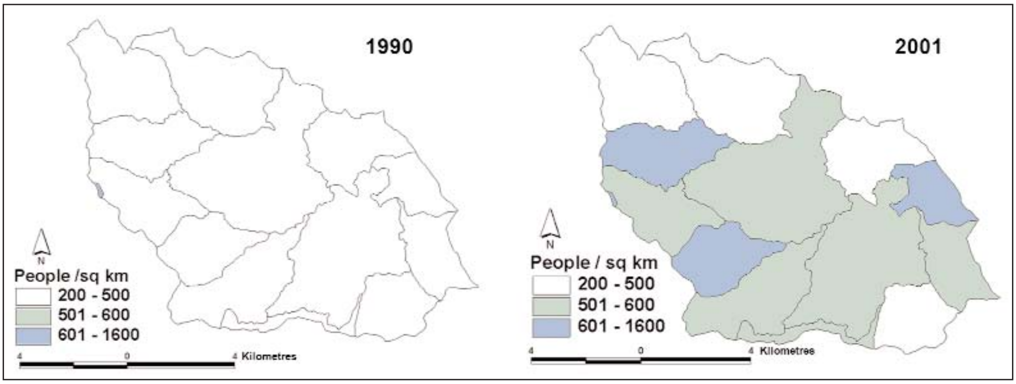

Figure 15: Population density in the Jhikhu Khola watershed

Table 9: **Estimated domestic water demand in the Jhikhu Khola watershed**

	Water demand for household purposes[a]			
	1990	1996	2001	2006 (projected)
Population	31,202	44,011	59,242	79,744
Annual water demand in m^3	261,941	369,472	497,337	669,451

[a] Calculated at 23 litres per person per day

In 1998 people started digging wells, and by 2005 more than 200 dug wells had already been constructed for domestic use.

Demand for agriculture

Agriculture is the main occupation of people in the Jhikhu Khola watershed, with 77% of watershed residents involved. However, the growing population builds pressure through intensification of land use (Figure 16). Over the last 24 years (1972-1996) non-irrigated land (bari) has increased by 4 % and irrigated fields (khet) by 2 %. Most of the suitable land has been converted into paddy, and grassland has decreased by 4%. Most shrubland has been turned into forest land; the former decreased by 12% and the latter increased by about the same amount (Table 10 and Figure 17).

In the 1950s the whole valley bottom of the Jhikhu Khola watershed was only used for growing rice in the monsoon and was left fallow during the rest of the year. During the monsoon, the farmers who lived at higher elevations came down to the valley each day to work their farms and returned home before dark. Farmers in the hills liked to keep the prime agricultural land for cultivation of rice and in many cases did not want to stay in the lowlands because of malaria. Nowadays the situation has changed due to improved medical facilities, eradication of malaria, improved access, and growth of communications and transportation. These improvements have led people to move from the hills to the valley bottom and to shift from subsistence to more commercial farming.

The Jhikhu Khola watershed is characterised by a very high population density and small landholding sizes — 0.56 ha median total landholding and 0.51 ha median agricultural

0: Land use change in the Jhikhu Khola watershed[a]

Land use types	1947[b]	1972[c]		1981[d]	1990[c]		1996[c]		Difference between 1972 and 1996 (%)
	Area (%)	Area (ha)	Area %	Area (%)	Area (ha)	Area %	Area (ha)	Area %	
Agriculture total	49	5,497	49	59	6,073	55	6,130	55	+5.7
Irrigated		*1,653*	*15*	*59*	*1,719*	*15*	*1,864*	*17*	*+1.9*
Rainfed		*3,844*	*35*		*4,354*	*39*	*4,266*	*38*	*+3.8*
	50	4,038	37	41	4,296	38	3,913	35	-1.1
Forest	*43*	*2,181*	*20*	*19*	*3,359*	*30*	*3,479*	*31*	*+11.7*
Shrub	*7*	*1,857*	*17*	*22*	*937*	*8*	*434*	*4*	*-12.8*
		1,184	11		466	4	762	7	-3.8
		422	4		306	3	336	3	-0.8

Total area 11,141 ha; [b]Indian Topographical Sheet; [c] PARDYP/ ICIMOD land use maps, scale 1:20,000, using land use mapping and Geographic (GIS); [d]Land Resource Mapping Project (LRMP 1986)

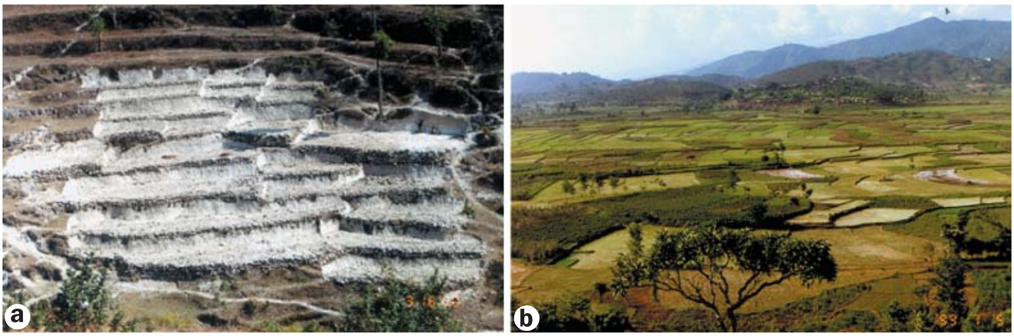

Figure 16: Agricultural intensification a) Conversion of grazing land to agricultural land; b) Cropping intensification in the fertile valley bottom

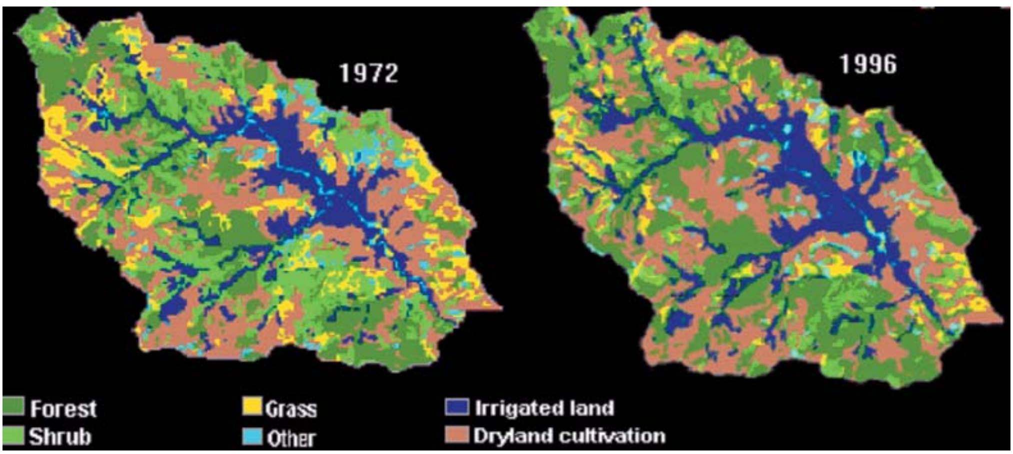

Figure 17: Map of land use intensification. Source PARDYP (2002b)

landholding (Livelihood Survey 2005). Farmers practise commercial farming with high inputs of labour, irrigation, chemical fertilisers, and pesticides with three to four crops grown per year at certain appropriate sites. Cropping intensity on irrigated agricultural land increased from 213% in 1994 (Juerg et al. 1999) to 226% in 2004 (Livelihood Survey 2005). Expansion of agricultural land and agricultural intensification adds to the pressure on water resources.

PARDYP analysed the crop water requirement in the Jhikhu Khola watershed based on the cropping pattern and area under different crops as estimated by the socioeconomic surveys of 1994 and 2004 (Annex 6). The analysis indicated increased demand of about four million cu.m water or 7% between 1994 and 2004 (Table 11). This finding is supported by the findings of the water demand and supply survey. The increased water demand is mainly during the pre-monsoon, and to a lesser extent the post-monsoon seasons and is due to vegetable farming.

Table 11: **Estimated crop water requirement for agricultural consumption in the Jhikhu Khola watershed**

Period	Crop water requirement for agriculture ('000 m^3)		
	1994	2004	Difference
Pre-monsoon (March, April, and May)	3,127	5,531	2,404
Monsoon (June to September)	36,006	36,450	444
Post monsoon (October-November)	7,231	7,762	531
Winter (December to February)	8,208	8,617	408
Total	**54,573**	**58,360**	**3,787**

Water Availability

A water availability study was carried out by analysing monthly, seasonal, and annual rainfall data measurements from the Jhikhu Khola watershed (Figure 18). The average annual precipitation was 1,338 mm; with upper and lower limits of probable annual rainfall of 1,538 mm and 1,138 mm, respectively (95% confidence). The upper limit for rainfall was 232 mm pre-monsoon; 1,141 mm in the monsoon; 102 mm post-monsoon; and 63 mm in winter.

Figure 18: Hydro-meteorological monitoring stations

On average 15% of total annual rainfall falls in the pre-monsoon period, 78% during the monsoon, 5% in the post-monsoon, and 3% in the winter. November to March are dry months; June to September wet; and April, May, and October in between. The probabilities of having no rain in the months of January, February, March, October, November, and December are 13%, 26%, 16%, 22%, 12%, and 24%, respectively (see Annex 7 for detailed analysis).

Management Options

A combination of small household-level technological options together with participatory and community-based approaches were found to be suitable for tackling the water problem. Technological options should be implemented in parallel with socio-cultural and institutional aspects for better management of water resources. The options can be divided broadly into three groups: methods to improve water infiltration into the soil, methods for water harvesting, and approaches for improving the efficiency of water use.

Improved infiltration

Terracing can be used to modify the slope of land from 50% to 5%, which reduces direct runoff and increases infiltration, thus improving soil moisture status and productivity (for a detailed description see Chapter 5).

Moisture stress is the major constraint for vegetation in drier sites. **Eyebrow-pitting** can be an option for harvesting rainwater and improving infiltration, thus improving soil moisture (Figure 19). PARDYP tested the use of eyebrow pits to help rehabilitate degraded dry land in Dhotra in the Jhikhu Khola watershed. The results were very encouraging (see also Chapter 5).

Catchment conservation is another option for improving infiltration. PARDYP supported the renovation and catchment conservation of the Barabot spring, facilitating formation of a user group in the process. Together with this user group, the source was protected using structural measures so that no direct flow of surface water could enter the source, thus reducing contamination. The user group was encouraged and supported to plant grass and tree seedlings in the catchment area of the spring (Figure 20). The flow of the spring was assessed to help design management strategies for the spring and address water scarcity (Figure 21). The results of the catchment conservation were promising; water availability increased and the neighbouring villagers and school began using the source in addition to the permanent users. Microbiological contamination and turbidity decreased (see Annex 8 for details).

The following possible management strategies were suggested.

- Explore other possible water sources to add to the spring tank.
- Protect the catchment area to prevent animal intrusion and maintain vegetation so that water yield during the dry period can be increased.
- Conservation of the catchment area through small vegetative erosion control structures like palisades to increase the infiltration and store the infiltrate water in

Figure 19: Eyebrow pits to improve infiltration on degraded land

Figure 20: Conservation of the spring at Barabot-Dhotra

Figure 21: Flow measurement of the spring at Barabot-Dhotra

the soil mantle — the water thus conserved later seeps into the spring. Selecting the right species for planting in the catchment areas will help keep evapo-transpiration low. Broadleaved species indigenous to the locality are preferable. Species like bamboo, pine, and eucalyptus that have high evapo-transpiration rates should be avoided.

- Close the spring with structural measures to protect it from direct runoff and stop fetching water directly from the spring, which will significantly reduce the water pollution. Instead siphon water from the spring to a collection tank and collect water from the collection tank through taps. Beyond the highest water level limit, the inflow water will be lost through underground seepage. Siphoning the spring water to the collection tank will save such underground seepage loss and help store all water for proper use.
- Set a seasonal limit on the quantity of water that each household can collect per day (total water yield per day in litres divided by number of households). This might vary with dependency on the source. For example, people living nearby depending solely on the Barabot spring might get more than other households that have access to other sources as well. It might also depend on the number of people in a household.
- Charge fees to users for regular maintenance as per the consumption rate or number of people in the household.

Water harvesting

Water availability is a major constraint to multiple cropping on rainfed agricultural land. Traditionally, upland farmers are restricted to a single crop while counterparts in the valley bottom with irrigation facilities grow multiple crops. One possibility for increasing water availability is to store excess runoff water in conservation ponds or use it to recharge groundwater, especially by putting it in a well for use when the crop water requirement is higher than rainfall. PARDYP tested the options of storing excess water in plastic-lined conservation ponds and in underground cisterns (tank) for later use in irrigation, as well as of rooftop rainwater harvesting and improving dug wells.

Traditionally, **conservation ponds** are very popular for storing excess runoff water, thus reducing erosion, to allow water to seep into the ground, and to improve soil moisture down-slope. The stored water is used for purposes such as watering cattle (aahale), raising fish, irrigation, and entertainment. Earthen ponds are simple, cheap, and durable but have high seepage losses that reduce effectiveness. Compacting heavy clay 30 cm deep on the floor of the pond can significantly reduce vertical seepage loss. Similarly, a 30 cm thick layer of heavy clay should be compacted between the wall and the ground to reduce horizontal seepage. Addition of cow-dung and puddling will help seal seepage pores. Watering of buffaloes in such ponds also helps reduce seepage. PARDYP tested lining of ponds with an high density polythene sheet or SILPAULIN (multi-layered, cross laminated, ultravoilet stabilised plastic sheet) to reduce seepage (Figure 22). Conservation ponds can be integrated with drip and sprinkler irrigation systems, and vegetable and fish farming to enhance their economic benefit.

Figure 22: Plastic lined conservation ponds

Surface runoff harvesting can be combined with **storage in underground cisterns** to save evaporation loss. PARDYP built two underground cisterns with local people on a dryland slope at Kubinde (10 m^3 capacity) and Hokse (30 m^3 capacity) as a pilot test (Figure 23). Water collection canals with sediment trapping mechanisms were constructed to drain runoff water to the cistern. Water was siphoned out through a flexible polythene pipe for irrigation. Local materials like stone and sand were collected by farmers, and other materials such as cement and good quality sand were paid by the project. The 10 m^3 cistern cost about US$ 365 and the 30 m^3 cistern cost about US$ 1,000. The farmers with the 30 m^3 cistern initially used it to provide irrigation water for vegetable farming, now it is used to support poultry farming. The 10 m^3 cistern was not much used and was almost abandoned, but in 2005 one farmer used the water collected in the cistern for the rice seedbed when water was unusually scarce. Cisterns are generally evaporation free. Although sediment-trapping mechanisms are provided, runoff water is not completely sediment free, and sediment collected in the tank must be cleaned regularly. Construction of large cisterns is very dangerous and difficult in the hills of Nepal where there are few highly skilled workers. The farmers involved in the construction of the test cisterns do not desire to make another attempt due to the high costs and the inappropriateness of the technology for mountain areas.

Figure 23: Underground water storage system

Roof-water harvesting is slowly becoming popular in Nepal. Different methods are used to collect the water. PARDYP tested roof rainwater harvesting using home-constructed ferro-cement jars for water collection (see Annex 9 for details). Thirteen jars were constructed in the Jhikhu Khola watershed and 9 in the Yarsha Khola watershed (Figure

24). The results showed that the system was appropriate for filling gaps in drinking water supply. The total cost of one jar and gutter system (2,000 litres capacity) ranged from NRs. 6,000 to 8,500 (approx. US$ 85 to $120) depending upon the distance of the construction site from the roadhead and the number of systems constructed in one locality. The PARDYP water demand survey indicated that average daily water use per person is about 23.2 litres, so a 2,000 litre jar can meet the domestic water demand of a family of six for about a fortnight (Annex 9, Table 2). Rainfall analysis at five different sites – Tamaghat, Kalikasthan (Dhulikhel), Bela, Bhetwal Thok, and Acharya Tole – indicated that harvesting water from a roof area of 20 m^2 could fulfil all water needs of a family of 2-4 people from June to September, and 30, 80, and 40% of the total water needs in April, May, and October, respectively (Annex 9, Table 11). The roof area can be increased by adding a plastic sheet to collect water. This is needed where natural water sources are distant or scarce. Doubling the roof area doubles the quantity of water collected, therefore the supply period will also be doubled as long as the jar is sufficiently large. Based on cumulative weekly rainfall and the total monthly runoff harvested, a minimum jar size of 1,000 litres is recommended to collect water for a family of 2-4 and a jar size of 2,000 litres for a family of 5 or more. A jar size of 500 litres may be too small to be useful even for a small family, since the rain is not uniformly distributed in each month.

Groundwater is increasingly used to address the increasing water demand caused by swelling population and intensification of agriculture. In the Jhikhu Khola watershed, the number of **dug wells** increased to more than 200 in 2005 from just a few in 1998. PARDYP monitored the monthly water level in the dug wells from August 2000 to December 2005 to assess the dynamics of the shallow groundwater table (Figure 25). The water table measured from the soil surface at the wellhead showed very different patterns in different wells. In most of the wells a clear seasonal pattern was visible with a recharge period lasting from one to four months, usually around May to August, and a recession period lasting from August to April or May. The water table in the dug wells was higher during the monsoon and gradually decreased during winter, dropping to a minimum during the dry pre-monsoon period (Annex 10). The water levels in the dug wells ranged from a minimum of 2.5m to a maximum of 10.5m. Most of the wells

Figure 24: Roof-water harvesting system

Figure 25: Monitoring the water table in dug wells

showed a decrease in water table with cessation of rainfall. Wells located on the slope close to the top of a continuous ridge (Annex 10, Figure 2) were recharged very fast,usually the maximum water level was reached within one to two months of the onset of the monsoon, however the water table dropped very quickly after rainfall ceased. Wells located near a stream showed only a slight seasonal pattern and very low differences between high water table and low water table. These wells benefit from direct recharge via river flow. Overall the study showed that dug wells can be a good source of drinking water as well as water for irrigation. Wells should be located near streams to get more water yield. Qualitatively, wells must be properly constructed to avoid microbiological contamination and leaching of chemicals.

It is important to understand the **water balance situation** in order to plan water management effectively. PARDYP analysed the water balance in the Jhikhu Khola watershed first dividing the area into two zones, one above and one below 1200m elevation (Annex 11). The overall water balance was in surplus in the upper zone and in deficit in the lower zone (Annex 11, Table 5), but there were deficits from October to March in the upper zone and from October to May in the lower zone (Figure 26). Water availability for irrigated (khet) land was in deficit from October to March and in June in the upper zone, and throughout the year except in July and August in the lower zone. Water was deficit in rainfed (bari) land from November to April in both zones (Annex 11). Overall, the watershed had a surplus of about 5.5 million m^3, about 4% of the total rainfall, but with a seasonal deficit from September to May.

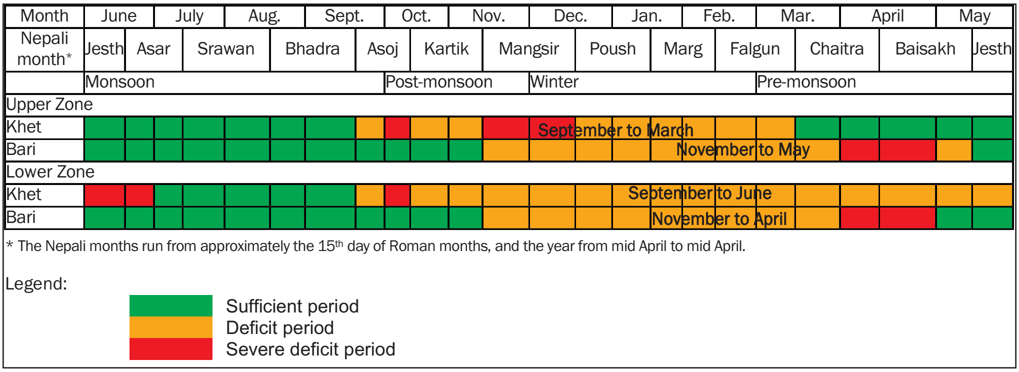

Figure 26: Overall water balance in the Jhikhu Khola Watershed

It is possible to **harvest runoff water in a pond** and use it when needed to fulfil the crop water requirement for small-scale vegetable farming in rainfed outward sloping agricultural lands. Similarly, efficient **management of irrigation canals** is a major option for fulfilling the water demand of irrigated (khet) land. These options not only supply water to the fields but also recycle sediment and nutrients back to the land, reducing sedimentation downstream and increasing soil fertility. The water balance analysis indicated that harvesting runoff is a potential option to fill all additional crop water requirements in September and 65% of requirements in November in the upper zone, but is not very useful for other months. In the lower zone, such harvesting could fill all additional crop water requirements from September to January and 40% of requirements in February. In order to fill the additional water requirement for a hectare of rainfed land, a pond of area 200 m^2 and effective pond height of 1.25m is recommended for the upper zone for the months of September to October and of area 150 m^2 in the lower zone for the months of September to January. The catchment area required for these ponds is about 3 ha in the upper zone and about 2 ha in the lower zone.

A **strategy** must be developed which emphasises and promotes the construction of irrigation canals, runoff harvest ponds, dug wells, conservation ponds, and check dams to address water management in the Jhikhu Khola watershed for commercial cultivation. Efficient water use technologies must also be introduced.

Efficient water use

Water requirements can be reduced by using available water efficiently. PARDYP has demonstrated various options for this.

Drip irrigation – a method of watering plants by delivering drops of water in a controlled way to plant root zones – is an effective way of reducing the water requirement for vegetable farming. In the PARDYP Water Demand and Supply Survey in the Jhikhu Khola watershed, 33% of respondents mentioned irrigation water shortages, particularly during the pre-monsoon season. Farmers in the Jhikhu Khola watershed have been growing high-value cash crops due to the easy access to the Kathmandu market, especially spring vegetables such as bitter gourd, cucumber, cauliflower, and tomato grown during the pre-monsoon period (March to May) when there is a great scarcity of water. Although pre-monsoon rain partially fulfils the crop water requirement, there is an unmet requirement of about 2 million m^3 of water (Table 12). PARDYP tested drip irrigation in the Jhikhu Khola watershed (Figure 27). The system consisted of a water tank and a network of pipes with drippers at predetermined intervals. Drip irrigation allows slow and precise delivery of water around the root zone, saving about 60% of water in all soil types compared to bucket irrigation without reducing yield. It also helps to mature the crop earlier; in the case of bitter gourd, the harvest was three weeks earlier than usual. This helps the farmers to sell the product for a higher price. Drip technology saved 50% in labour compared to the conventional method of bucket irrigation. Drip irrigation is very useful for growing spaced crops on level ground. Due to more efficient water use, drip irrigation helps to increase the area under vegetable cultivation and in a few cases allows cultivation of fallow land (after monsoon crops), which contributes to additional household income. About 100 farmers in the watershed have now adopted drip irrigation, and the area under vegetable cultivation has increased.

Figure 27: A drip irrigation system

Table 12: **Water requirement** (Source: Annex 6, Table 4)

Year 2004		Crop water requirement in m^3					
	Area in ha	March		April		May	
Crop grown		1	2	1	2	1	2
Tomato	192	151,660	185,914	279,102	351,695	334,988	167,050
Spring vegetable	83	33,930	62,402	121,972	138,664	130,226	82,777
Total crop water requirement in m^3		185,590	248,316	401,074	490,359	465,214	249,827
Crop water requirement pre-monsoon in m^3		2,040,385					

Sprinkler irrigation is another option for efficiently irrigating high-value cash crops. This method was demonstrated at different locations in the Jhikhu Khola watershed (Figure 28). At the beginning (2002 and 2003), PARDYP supported 15 farmers. A farmers' perception survey was carried out in 2004 to assess the condition and performance of the sprinkler systems. The farmers had been using the technology with different cash crops on areas of 64 to 1,524 m^2. Sprinkler irrigation was used to irrigate up to six vegetable crops on a rotational basis. About 80% of farmers had been growing garlic, 70% onion, 55% cabbage, 45% cauliflower, 20% shallots, and 10% potato. A few farmers were also growing bitter gourd. Most of the farmers collected tap water in a traditional pond (wastewater collected after household use), which then flowed through a polythene pipe to run the sprinkler. Some also used water from an irrigation canal and a few from water harvested from the roof (during the monsoon) stored in a cement jar.

Figure 28: Sprinkler irrigation

Farmers thought that sprinkler irrigation had the following advantages:

- it is appropriate for irrigating sloping as well as level land;
- it saves time – once installed and sprinkling it does not need to be looked at for 3-4 hours;
- it provides uniform application of water;
- it reduces soil loss from sloping land and increases soil moisture;
- it is easy to handle and transport to the desired location;
- a single set is sufficient for 2 to 3 households;
- the water drives away insects;

and the following disadvantages:

- it requires frequent maintenance against blockage of holes;
- it needs sufficient head pressure and is therefore not very useful for flat land;
- sometimes it stops functioning (does not rotate at all and disconnects from the main pipe).

The differences perceived by farmers between drip and sprinkler irrigation systems are summarised below.

Sprinkler Irrigation	Drip Irrigation
Useful in closely grown crops such as garlic and onion	Useful for crops planted widely apart such as bitter gourd and cauliflower
Can be used on sloping land	Difficult to use on sloping land
Easy to transport, and possible to use for different crops in rotation	Difficult to transport; it is fixed for one crop and stays the whole growing season
Repels insects	Does not repel insects
Easily available in local market and cheap	Not easily available in local market and expensive
Requires more water therefore requires perennial water source	Requires less water and is highly water efficient
Requires frequent maintenance against blockage	Requires low maintenance
Requires sufficient head pressure, therefore not applicable in flat areas	Low head pressure is adequate for irrigation
Likely to be stolen because of easy dismantling	Difficult to dismantle once crop is grown

Another useful approach for reducing crop water requirement is the **system of rice intensification (SRI)**. In this system, 8-12 day-old 2-leaf seedlings are planted at a wide spacing (generally 25 cm x 25 cm or even wider). Only a small amount of water is applied when the field is prepared for transplanting, and the fields do not require continuous flooding except during the flowering stage. If the land starts cracking due to drying, light irrigation is required to moisten the soil. Alternate dry and moist soil conditions improve aeration thus helping the plants to grow vigorously. PARDYP tested SRI in the Jhikhu Khola watershed as an option for improved productivity, both in the complex of the Spice Crop Development Center and on farmers' fields (Figure 29). Farmers found that SRI consumed 50 to75% less water than the traditional method. It reduced frequency of irrigation, conflict among irrigation water users, and riser failure caused by stagnant water (see Annex 12 for details). However, it is essential to have full control over the irrigation and drainage.

Different crops require different amounts of water; therefore **modifying cropping patterns** can also help to mitigate water scarcity to some extent. A case study was analysed on the Juke irrigation canal – one of the large irrigation canals in the Panchkhal valley irrigating about 45 ha of valley agricultural land. The total crop water requirement for the current cropping pattern is about 1.66 million m^3 of irrigation water annually. In addition to the water provided by existing irrigation canals and rainfall, the present cropping pattern demands additional irrigation water of 598,600 m^3 for optimum growth. Modifying the cropping pattern in various ways can significantly reduce the additional water requirement (Table 13 and Annex 13). Population growth, agricultural intensification, and gradual advancement of people's lifestyles, have increased water demand (Figure 30). Rainfall records do not indicate any significant change in the climatic pattern over the last 50-60 years. Difficulties in water availability are inherent in the seasonal characteristics of the monsoon and exaggerated by human behaviour. Changing cropping patterns is an appropriate way to help manage potential water deficits.

Figure 29: System of Rice Intensification

Table 13: **Additional irrigation water requirement**

	Additional irrigation water requirement in m³					
	Pre-monsoon	Mon-soon	Post-mon-soon	Winter	Total	Reduction from present pattern
Present cropping pattern	375,114	32,540	24,205	166,749	598,609	
Changing wheat to oil seed	371,869	32,540	17,200	146,897	568,506	30,103
Changing 50% of the potato to winter vegetable	375,114	32,540	17,752	149,964	575,371	23,238
Changing wheat to oil seed and 50% of the potato to winter vegetable	371,869	32,540	17,200	132,496	554,105	44,504

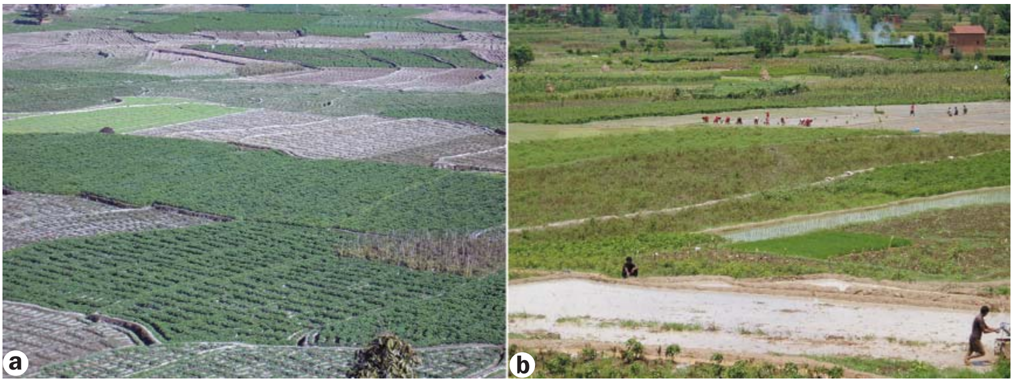

Figure 30: Intensive cropping patterns a) winter b) summer

Lessons Learned and Recommendations

Water demand and supply

- Total domestic water demand in the Jhikhu Khola watershed has more than doubled over the last 15 years (1990-2004) due to increased population.
- Agricultural water use in the Jhikhu Khola watershed has increased by about 4 million m³ over the last 10 years (1994-2004).
- Annual rainfall in the watershed varies, but long-term data do not show any decrease in annual rainfall.
- Water scarcity in the watershed seems to be caused by increased demand rather than reduced rainfall.

Management options

Improved infiltration

- Levelling sloping agricultural land increases infiltration thereby improving soil moisture and reducing nutrient loss, which help productivity.
- Terraces can be developed over two or three years by introducing biological barriers and using appropriate cultivation practices.
- Eyebrow pitting is a very good way of increasing soil moisture status, creating a favourable micro-environment for plants to grow.
- Protecting a spring source and its catchment area from pollution improves water quality.
- Vegetative measures in the catchment area improve the water regime of a spring.
- Collecting spring water in a tank improves water availability.
- Flow measurement in a spring can play a crucial role in preparing strategies to reduce conflict in areas of water scarcity.

Water harvesting

- Storing water in conservation ponds is an important option for meeting water demands.
- The local technology of lining ponds with a clay layer and puddling reduces seepage loss in earthen ponds.
- High density plastic sheet or SILPAULIN is an effective lining material to reduce seepage loss.
- Large underground cisterns are dangerous, costly, and not recommended in earthquake-prone hill areas, and are generally not applicable for irrigation because of the size required to store enough water.
- Underground cisterns could be used to store drinking water to reduce evaporation loss.
- Wells are an important source of water to manage water scarcity.
- Wells located close to the top of a continuous ridge recharge quickly with the onset of rain.
- Water table fluctuation in wells close to streams is low, but high in wells located close to the top of a continuous ridge.
- The water table in wells located at the foot of a slope decreases with decreasing rainfall.
- Roof-water harvesting is an important option to fulfil the needs for drinking water in water scarcity areas.
- A minimum of 1,000 litres storage is essential for useful roof-water harvesting. Although water need is greatest from October to March, more water can be collected from May to September, and roof-water harvesting is generally more pragmatic during this period.
- The overall annual water status for agricultural land in the Jhikhu Khola watershed is in surplus, except for irrigated land in the lower zone. However, all agricultural land had seasonal water scarcity with a particular deficit from October to April.

- Runoff harvest can potentially fill a significant additional crop water requirement for rainfed land in September and November in the upper zone and from September to February in the lower zone of the Jhikhu Khola watershed.
- The recommended pond size for a collecting pond for surface runoff to fill the additional water requirement for a hectare of rainfed land is 200 m^2 with an effective pond height of 1.25 m in the upper zone and 125 m^2 in the lower zone of the Jhikhu Khola watershed. The recommended catchment area is 3 ha in the upper zone and 2 ha in the lower zone.
- Water harvesting measures such as conservation ponds and irrigation canals not only fulfil crop water requirements but also conserve sediment and nutrients.
- Further research is needed on runoff harvest coefficients, stream flow coefficients, and the water requirement of other crops.

Efficient water use

- Drip irrigation is an efficient option for crops grown on level surfaces at a distance from each other such as bitter gourd and cauliflower; it saves up to 60% of water compared to bucket irrigation without decreasing production.
- Drip irrigation saves about 50% of labour compared to bucket irrigation.
- Drip irrigation helps crops to mature earlier, enabling the farmers to get better prices. The early maturation is due to uniform moisture availability for efficient photosynthesis.
- Drip irrigation is not an appropriate option for closely grown crops such as garlic and onions.
- Availability of drip irrigation equipment is still a constraint in the hills of Nepal.
- Sprinkler irrigation is a time saving irrigation option for closely grown crops in the hills where sufficient head pressure can be easily achieved.
- The SRI allows paddy fields to be cultivated with less water, which helps to reduce irrigation conflict in the community.
- SRI increases yield and requires less inputs such as seedlings and labour than traditional methods.
- For successful SRI, it is essential to control irrigation and drainage to maintain soil at the right moisture level.
- Modifying cropping patterns can reduce crop water requirements to some extent, and therefore could be an important strategy in irrigation water management.