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Water Conservation for Livelihoods and Labour Constraints: A Case Study from Nepal

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Abstract: Cash crop production, increased demand for water and high workloads are raising concerns about the sustainability of intensive farming systems in Nepal. Water conservation technologies are seen as a potential option for producing off-season cash crops, and reducing water demand and labour for water collection. Their appropriateness was evaluated from biophysical and social perspectives by combining hydrometric monitoring, gender and water use surveys and field trials of drip irrigation systems. Results demonstrated domestic and irrigation water shortages prevalent from March to June, and an increased demand for water as farmers move towards market-based production. Women's workloads were high, 13.5 hours per day, necessitating labour reduction as a condition for small-scale water projects. Low cost drip irrigation trials quantified high water use efficiency under a deficit water regime, and capital costs could be paid off in the first crop. Labour was a significant component of variable costs making efficient technologies attractive as demonstrated by the 100+ systems adopted in the watershed since the trials in 2001.

Key words: Drip irrigation, Nepal, gender, workloads, water balance.

Introduction

Water is an unequally distributed resource both temporally and spatially, and under monsoon climatic conditions extremes in water availability occur between wet and dry seasons. Agriculture typically utilizes some 70 to 80 percent of the water withdrawn for human use (FAO, 2004; Gleick, 2004), and water withdrawals for dry season irrigation may heighten water shortages and lead to conflicts over downstream water use (Gleick, 2004; Wolfe, 2005). Technologies for efficient water use may result in conservation but their application, particularly in third world countries, will not depend solely on technological efficiency. Social and economic factors such as implementation costs and labour requirements may also contribute to the reduced adoption of new management practices (Rosegrant et al., 2002).

Livelihood is an important consideration in development activities particularly at the local level where farmers may be more interested in income opportunities than production per se (Chambers, 1988). In rural mountain communities where cash income is limited, the production of market crops may provide farmers with a viable option particularly if produce can be marketed in the dry season when prices are favourable (Brown and Kennedy, 2005; von Braun, 1995). Irrigated agriculture associated with rural livelihood options are a potential mechanism for poverty reduction, particularly if small scale producers are not excluded (Smith, 2004), and low cost drip irrigation systems may fill this niche. Labour however is a further constraint to the participation of small scale producers in the cash market economy.

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Where workloads are high and water is scarce, farmers will be required to make tradeoffs in the allocation of household labour. And in the case of water, its collection and use for domestic, livestock and components of irrigated agriculture are largely the responsibility of women in many parts of the world (Blennerhassett, 1999; Niamir-Fuller, 1994; UNESCO, 2003).

Through a case study example we will illustrate how water, livelihoods and workloads interrelate, and the implications for the sustainability of small water projects. By quantifying water use and availability, and gendered roles and responsibilities we will illustrate how high workloads and the increased demand for water are contributing to unsustainable water use. Water harvesting and drip irrigation are then examined in relation to workloads to assess combined options for water use efficiency, livelihoods and labour.

Study Area and Methods

Case Study Watersheds

The Middle Mountains of Nepal are experiencing rapid increases in population, changes in farming systems as market opportunities expand, and corresponding land use pressures. The two case study watersheds in the Middle Mountains of Nepal (Figure 1) represent the range of agricultural conditions found within the region. The Jhikhu Khola watershed, located 40 km east of Kathmandu, has market access via road and is representative of intensive agriculture (Brown and Shrestha, 2000). The Yarsha Khola watershed, 200 km east, is largely a subsistence-based agricultural system (Table 1). Both watersheds are experiencing water shortages during the dry season (although to different extents) and residents are raising concerns about water

Figure 1: Location of the case study watersheds, showing public water sources.

Table 1: Watershed characteristics

	Jhikhu Khola	*Yarsha Khola*
Area	11,141 ha	5,400 ha
Location	40 km E of Kathmandu	200 km E of Kathmandu
Production	Market connection Rice-potato-maize Maize-wheat/ potato-tomato	Largely subsistence Rice-wheat-maize Maize-millet-fallow
Population	4.37 people/ha (1996)	3.86 people/ha (1996)
Water issues	88% report irrigation water shortages, 68% report perennial shortages in domestic water	75% report either drinking or irrigation water quality or quantity problems

quality. The watershed comparison illustrates water use and labour constraints, and allows us to evaluate management options in a more pro-active manner, as agriculture intensifies.

Water Use and Water Monitoring

A water use survey, hydrometric monitoring, and water quality sampling were employed to assess the status and dynamics of the water resources within the watersheds, and to understand issues of concern from a community perspective. The water use surveys conducted in 1998-99 reflect gender-based roles and responsibilities in water management. Female and male enumerators interviewed female and male household heads respectively. Women were asked about household and animal water supply, men about agricultural water supply, and both their perception on water issues. In Jhikhu Khola, 356 respondents were interviewed, and 436 in Yarsha (Merz et al., 2003b). A community-based survey of water sources was conducted to spatially locate springs and other water sources. Stream flow has been monitored at five stations since 1992 in Jhikhu Khola, and at six stations since 1997 in Yarsha Khola, and rainfall at 10 and 11 stations respectively. Water balances were calculated using meteorological data to determine critical months for water shortages (Merz, 2003). In the more intensively utilized Jhikhu Khola watershed, water quality in stream, drinking water sources and dug wells were analyzed for chemical, physical and biological parameters. Twenty streams, 31 drinking water sites and 14 dug wells were sampled. Analysis included nitrate, phosphate and coliforms (Merz et al., 2005).

Gender and Socio-economic Surveys

Gender and socio-economic information was compiled simultaneously with biophysical data collection by integrated teams of male/female biophysical and social scientists working together with local co-researchers. Resource use surveys were conducted at 200 sites in Jhikhu Khola in 1994 and 337 sites in Yarsha Khola in 1997, with more detailed socio-economic information gathered from 85 and 75 households respectively. Simultaneous but separate female/male farmer interviews were conducted to account for the typical division of labour and to compare perceptions of female and male farmers. Information on gender roles and responsibilities and labour were compiled through interviews, daily diaries and time allocation studies. In addition, 27 households interviewed in 1989 were re-interviewed in 1996 to evaluate change (Brown, 2003).

Water Harvesting and Drip Irrigation Trials

Water harvesting trials of both rooftop water collection and underground cisterns were evaluated from 1998 to 2001 for small scale irrigation and drinking water supply respectively. The "Thai-jar" rainfall rooftop collection method was used to re-direct rainfall into a gutter system leading to a holding tank. Trial systems (n=21) were constructed locally and cost, water use, sanitation and labour were evaluated. Demonstration cisterns (n=2) were constructed based on a modified Chinese design to collect surface water for underground storage (30,000 L). Cost and water use were determined (Merz et al., 2003a).

A comparison of irrigation methods under different watering regimes for cash crop production was conducted through experimental farm and two on-farm trials in 2000-01. Cauliflower was grown using low cost drip irrigation, conventional drip irrigation and hand watering under daily irrigation, alternate day irrigation and deficit irrigation schemes. Soil volumetric water content, biomass production, water use efficiency and economic profitability were measured (von Westarp et al., 2004).

Results and Discussion

Water Use and Availability

Households in the Middle Mountains draw water from a wide range of small sources including springs, wells and streams (Figure 1). In the Jhikhu Khola watershed 322 sources were documented as "relevant" to local users, 215 sources in Yarsha Khola. The majority of these water sources are owned and maintained by communities (82% and 95% in the two watersheds), and typically a single source is used only by a small group of households (e.g.

18 households per source in Jhikhu Khola on average). Irrigation and drinking water quantity are the main concerns reported by local residents (Table 2). Water quality is more of a concern to residents in Jhikhu Khola where agriculture is intensive and agro-chemical use is high.

Table 2: Water issues of local residents

Concern	*% Respondents*	
	Jhikhu Khola	*Yarsha Khola*
Irrigation water quantity	33	41
Drinking water quantity	29	36
Drinking water quality	27	9

Water shortages are prevalent for both domestic and irrigation water during the dry winter months. For example, in Devbhumitar, a Jhikhu Khola community, farmers that reported adequate water for their winter crops dropped from 66% in 1985 to 16% in 1999. Areas within the Jhikhu Khola in which water demand has increased are those areas where off-season vegetable production is market driven and the use of kerosene water pumps is becoming widespread. In a second Jhikhu Khola community, Baluwa, the number of farmers reporting irrigation as the most significant issue constraining production has increased from 43% to 60%, and conflicts over downstream water use are emerging where traditional management systems were once effective. Water balances calculated from climatological data indicate the highest risk of very dry conditions during the pre-monsoon season, April to May (Figure 2). During this time rainfall is low and often variable, and evapotranspiration is high, resulting in the lowest runoff and highest water deficits (Merz, 2003). The post-monsoon and winter seasons have low precipitation, but water deficits are only moderate due to low evapotranspiration. This season has the potential for greater water use efficiency.

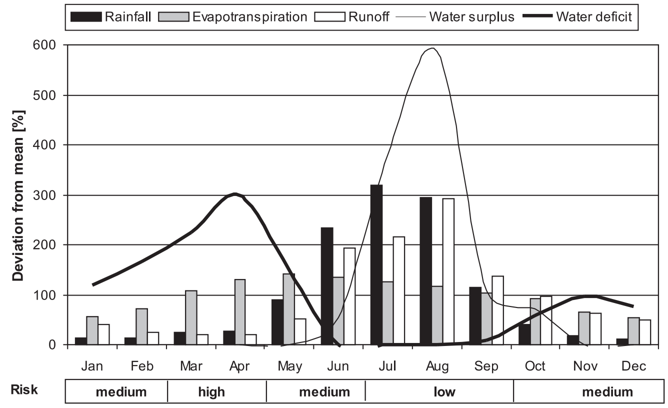

Figure 2: Temporal distribution of water balance in Jhikhu Khola and associated risk of water deficit.

In the Jhikhu Khola watershed, farmers also raised concerns about drinking water quality. Selected water quality parameters for streams, drinking water sources and shallow wells are listed in Table 3. All sources show significant contamination. Only rarely are fecal coliforms absent, phosphate levels are elevated, and none of the shallow wells tested were potable and require treatment prior to use. High phosphate levels are related to human activity near sources (washing clothes and bathing) and the application of DAP fertilizer to potatoes grown in winter (Schaffner, 2003). Dealing with water quality simultaneously with water quantity is vital for water projects and human health.

Table 3: Selected water quality parameters

Water source	*Parameter*	*n*	*# times sampled*	*Mean*	*% exceedence[1]*	*WHO guidelines*
Streams	Phosphate (mg/L)	20	4	0.54	61	0.4
Drinking water sources	Total coliform (MPN/100 ml)	31	2	1800+	95	10
	Phosphate (mg/L)	31	3	0.60	60	0.4
Dug wells	Ammonia (mg/L)	14	3	0.53	67	1.5
	Nitrate-N (mg/L)	14	3	5.8	19	10
	Phosphate (mg/L)	14	3	0.85	69	0.4
	Total coliform (MPN/100 ml)	14	3	150+	98	10
	Fecal coliform (MPN/100 ml)	14	3	2	17	0

[1] % occurrence that sampled parameter exceeded WHO guidelines.

Gender Roles and Workloads

Understanding gender divisions of rights, responsibilities, work and knowledge is an important step in implementing better development options as we consider who is impacted by new technologies and how. Water collection, livestock watering, irrigated agriculture, decision-making and overall workloads are central components of gender roles related to water. Table 4 summarizes these engendered responsibilities for the case study watersheds.

The collection of water for domestic purposes is almost exclusively the responsibility of women (92% in the two watersheds). Women spend 15 minutes to two hours per trip and on average make five trips per family per day, accounting for some 2.5 hours per family per day. The average per capita water consumption in Jhikhu Khola and Yarsha Khola respectively is 21 and 23 L/day, significantly less than the 50 L/day recommended for rural water supply design and the proposed water requirements as a basic human right (Gleick, 1996; WHO, 2003).

Livestock care and watering are also tasks relegated largely to women and/or children. Animal watering, animal grazing and fodder collection range from 67% to 98% responsibility of women and girls. On an average women spend 45 minutes per day watering animals, and households typically use 70-105 L/day for their animals, roughly 60% of that used per day by a typical household of 6.5 persons. The responsibility of women for livestock care has increased in the last decade (Figure 3). The

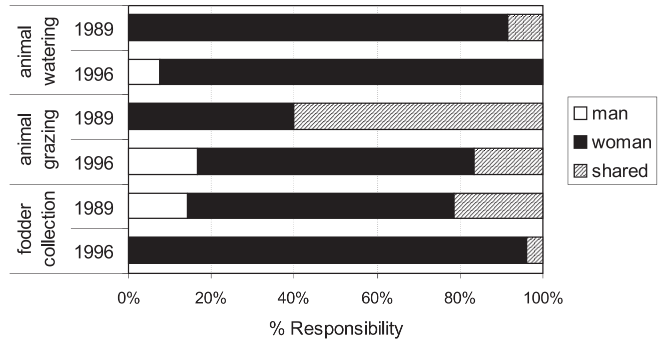

Figure 3: Responsibility for livestock care in Jhikhu Khola, 1989-1996.

commercialization of milk production in the Jhikhu Khola watershed has increased women's workloads as the number of female water buffalo has increased. Where households are involved in commercial milk production, women spend an average of 4.5 hours per day collecting fodder, watering animals and milking animals.

In irrigated agriculture, gender roles are task specific. While men are largely responsible for irrigation and terrace maintenance, women are active in planting, weeding, harvesting and applying compost. In Yarsha Khola (subsistence agriculture) women spend an average 11.6 hours per day in activities related to agriculture, compared to 7.9 hours per day by men. Despite their active role in agriculture, women have a lesser role in decision-making. On average, men are responsible for 68% of the decision-making; however variability between

Table 4: Gender responsibilities for major tasks related to water and water management

Task		*% Responsibility*[1]			
		Female		*Male*	
		Jhikhu[2]	*Yarsha*[3]	*Jhikhu*	*Yarsha*
Domestic	Water collection	92	92	8	8
Livestock	Animal watering	92	88	8	12
	Animal grazing	75	67	25	33
	Fodder collection	98	90	2	10
Agriculture	Terrace maintenance	12	<1	88	88
	Irrigation	8	6	91	90
	Planting	49	64	51	20
	Harvesting	70	45	30	31
	Applying compost	84	53	16	33
Decision making	Household money	46	33	54	67
	Buy/sell animals	0	18	100	72
	What to plant	6	32	94	68
	When to plant	-	34	-	66

[1] Percentages may not total 100 due to contributions from exchange labour (parma)
[2] Jhikhu Khola $n = 27$
[3] Yarsha Khola $n = 75$

households is large. In 15% of the sampled households men make all farm management decisions without consultation, 31% men work off-farm for six months or more per year, and there are two female-headed households (Brown, 2003).

Total workloads are high, particularly for women; 13.5 hours per day in Yarsha Khola compared to 9.7 hours per day for men. Women are responsible for the collection of water for domestic and livestock purposes, and play an important role in irrigated agriculture. Reducing the workload of those responsible for the collection of water is consequently an important component to the adoption and sustainability of small-scale water projects.

Water Conservation for Livelihoods and Labour Constraints

High workloads and the increasing demand for water for market production by local farmers points towards the need for alternatives that combine water collection, efficient water use, labour savings and a livelihood option. Water harvesting, combined with drip irrigation for cash crop production provides one such combination.

Water harvesting trials with roof top water collection in jars (n=21) were effective both in terms of cost and labour, but their storage capacity was relatively small. Monsoon rainfall was directed from the roof of a dwelling into a gutter system leading to a 5 m^3 holding tank (jar). The capital cost of $80 per unit is reasonable, and material and labour requirements are low. The "jar" system provided a potable water source, was effective in reducing workloads for water collection (Table 5), and water use increased slightly. However, as the size of the jar is limited (5 m^3) the water collected only supplements domestic water supply.

Water harvesting of surface water stored in underground cisterns (n=2) had a high cost ($800 for 30 m^3) to construct cisterns, which would store enough water for off-season vegetable production. Construction of the system required 100 person-days including excavation, masonry, and construction of siltation ponds. The cisterns were effective in supplying supplemental irrigation water, reducing sediment and supporting cash crop production during the dry season; however small-scale farmers were not able to afford the initial costs.

Table 5: Reduction in women's workload with roof water collection jars

Activity	*Before*	*After*
Collection distance	564 m	0 m
Collection time	91 minutes	22 minutes
Water use	15 L/day	17 L/day

Drip irrigation trials suggest that low cost drip systems are a viable option to produce off-season vegetables both in terms of economic and labour benefits. Cauliflower yields under deficit irrigation were significantly greater with low cost drip irrigation than conventional drip irrigation or hand watering. Irrigating to meet full crop water requirements with an evening only schedule, gave the greatest yields for low cost drip irrigation and hand watering, while with a morning and evening watering schedule, hand watering outperformed both drip methods. Water use efficiency was greatest with deficit irrigation (Figure 4); a 50% reduction in water use resulted in only a 10-30% reduction in total cauliflower yield (von Westarp et al., 2004). Both hand watering and low cost drip irrigation are viable to increase food production in water scarce, small-scale farming; however economic and labour benefits are greater under low cost drip irrigation.

The economics (Table 6) of low cost drip highlights the efficiency. Capital costs are paid back with the first crop, and labour costs for "other activities" are significantly lower (<50%) than under hand watering. Thus by the second crop, low cost drip irrigation is economically more efficient, and long term profits are greater.

More than 80% of the labour costs are associated with the collection of water. If water needs to be carried long distances, the effective price of water is high and drip irrigation becomes an attractive alternative. Combining drip irrigation with water harvesting has the potential to combine efficiency and reduce labour; however the construction cost for surface water harvesting is

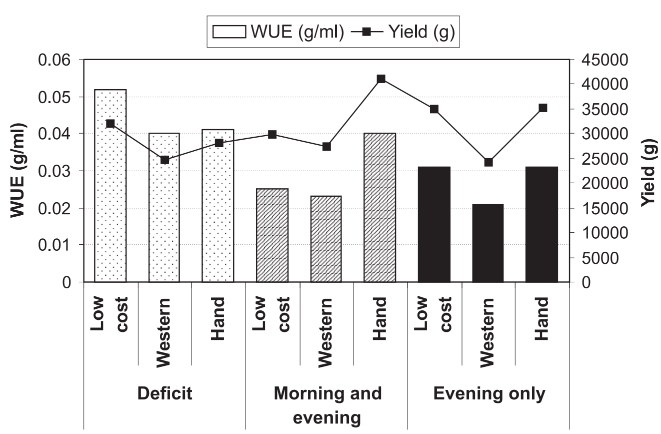

Figure 4: Water use efficiency and cauliflower yield for low cost drip irrigation, conventional drip irrigation and hand watering under deficit and full crop water requirement irrigation.

Table 6: Economics of low cost drip irrigation, irrigating to meet full crop water requirements

Costs		*$ USD*[1]
Capital	Drip system: 127 m^2 with 100 L drum	19.14
Variable	Agrochemicals	3.79
	Seedlings	4.57
	Labour: Collecting water	13.93
	Other activities	3.21
Total costs		44.64
Gross income	Cauliflower sales	54.86
Net income	After 1st crop	10.22
	After 2nd crop	20.35

[1]1 USD = 70 Nepali Rupees

prohibitively high. Drip irrigation remains attractive to small-scale farmers, however, as the relative amount of water that needs to be carried to grow off-season vegetables was reduced by approximately 70% compared to furrow irrigation (9050 L compared to 30,000 L). Since the trials conducted in 2001, more than 100 low cost drip systems have been adopted in the watershed.

Summary and Conclusions

We need to know how much water we have to effectively manage and allocate water resources. Water use surveys and water balances developed through local data collection (social and biophysical) were demonstrated to be effective methods to assess demand and supply, and potential options for water management. In the case study watersheds, water shortages are widespread and demand is increasing, particularly in the dry season when supply is limited. Water balance modelling pointed towards the use of water efficient technologies during the dry winter months when precipitation is limited but evaporation is low. Field trials demonstrated the water use efficiency of low cost drip irrigation, but labour and economic components were important for the success of this option.

To have impact at the local level it is vital to include an evaluation of workloads when assessing the sustainability of proposed options or policies, and specifically to address whose workload is impacted and how. If workloads are already a production constraint, technologies which focus on reducing workloads will have a better chance of success. As shown in this case study, women's workloads in the Middle Mountains of Nepal are high, and drip irrigation has the potential to reduce workloads related to the collection and transport of water, and the time required to irrigate small plots. Water harvesting too shows promise to reduce workloads related to water collection, but neither rooftop water collection nor cisterns have been widely adopted in the study area, largely related to storage capacity and cost respectively. Considering the affordability and impacts on livelihoods is clearly an important consideration from the perspective of poor rural farmers. Low cost drip irrigation for cash crop production was shown to have short-term affordability and positive livelihood impacts, resulting in its adoption with limited promotion.

Working in integrated teams of biophysical and social scientists, national and international researchers, local co-researchers and farmers allowed us to pool resources and take a more holistic approach to water use. Addressing the issue how women, water and workloads interrelate: balancing water demand and supply by combining water use efficiency, livelihoods and labour provides a mechanism to assess social and biophysical sustainability, and improve the chance of success of small-scale water initiatives.

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