Multiple sources for multiple uses: Household case studies of water use around Cochabamba, Bolivia

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Abstract

This paper reports on a series of household water-use case studies around the city of Cochabamba in Bolivia. In particular it examines the multiple use of domestic water supplies, and the use by families of multiple sources to meet their water needs for both domestic and productive activities. As the city expands, it is argued that productive water uses such as irrigation of gardens or *huertas* are likely to make significant demands upon new domestic water supply systems. These uses are equally likely to have an important impact, whether positive or negative depending on your viewpoint, on the overall availability of water resources as well as on the livelihoods of urban and peri-urban water users.

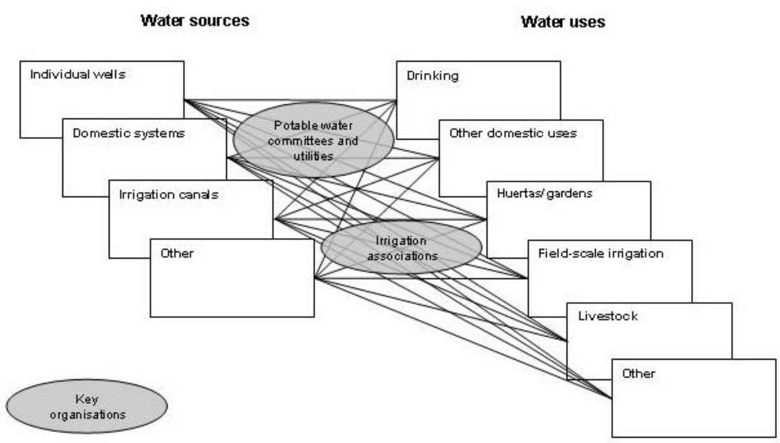
Keywords

Multiple uses, water supply, irrigation, urban, peri-urban, agriculture, Bolivia

Background

In general, different institutions and specialists are engaged in meeting the needs for domestic and irrigation water. Bolivia is typical of many developing (and developed) country situations in this regard. Community-based water supply committees or utilities provide the domestic water, and a hierarchy of irrigation committees, associations and authorities develop and manage irrigation water. This segregated or sectoral approach is increasingly being challenged internationally (Moriarty *et al*., 2003). On the ground, irrigation water is commonly used for livestock or domestic needs, and domestic water supplies are often utilised for small-scale productive activities (Figure 1). As we see later in this paper: wells, piped or other water systems, irrigation canals and other sources (like wastewater or tankered supplies) can normally be found being used for a wide spectrum of uses covering drinking, other domestic uses like washing, irrigation of small gardens, larger-

Figure 1 Multiple water sources and uses



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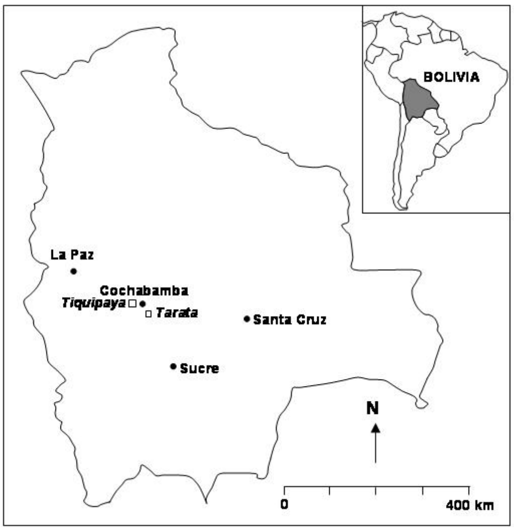
scale irrigation of fields, and for livestock. It is the norm to find multiple sources being used for any particular purpose, and for multiple uses to be associated with any particular source. People and communities therefore have an integrated approach to the use of water (in rural, peri-urban and urban areas) that is rarely mirrored by the institutions involved in planning, developing and managing their water supplies.

Figure 2 Location of study sites



This paper reports the findings of two studies on household water use undertaken by research students attached to the research centre Centro-AGUA in Cochabamba, Bolivia (Herbas *et al*., 2003; Hillion, 2003). Both studies, one in Tarata-Arbieto and the other in Tiquipaya, were small sample, detailed case studies of household water use patterns in these different areas around Cochabamba.

Study area

The city of Cochabamba in central Bolivia (Figure 2) lies at the edge of the Andes and within the upper part of the Amazon basin. The climate is mild but relatively dry, and with only a short rainy season between December and March, irrigation has a huge impact on agricultural production (Table 1). The city is surrounded by productive valleys that even in modern times remain bread-baskets for the country as a whole, while also being vulnerable to the impacts of urbanisation. Tarata is a small town to the south-east of the city, and Tiquipaya is located on the peri-urban fringes of the rapidly growing city.

Tarata

Tarata is located 35 km from the city of Cochabamba in the province of Esteban Arze. It is a small market town with a population of around 4000 people. The town is in an important agricultural area, especially following the extensive development of irrigation in the 1990s. The large Laka Laka dam on the Calicanto River and its catchment area are located in the municipality of Tarata. However, most of the downstream irrigated areas actually fall within the neighbouring municipality of Arbieto.

Table 1 Key background statistics for the study areas

	Tarata-Arbieto		Tiquipaya
Area (km^2)	326	124	320
Population (2001)			
-urban	3323	782	26732
-rural	5392	7034	11059
Pop. density (persons/ km^2)	26.7	63.0	118.1
Pop. growth (% 1992-2001)	0.39	2.04	11.23
Mean annual temperature (◦C)		16.4	
Average annual rainfall (mm)	478.5		561.5
Annual potential evaporation at Lake Angostura (mm)		1,883	
Altitude (masl)	2721		2610

Besides cultivation and livestock keeping, the most important economic activities in Tarata are fishing, making and selling *chicha* (a maize drink), ceramic pottery and fireworks. Relatively low returns from the main sources of livelihood in the area - 88%

of people work mainly in agriculture, livestock raising or traditional craftworks – have resulted in high levels of both temporary and permanent migration. In the province of Estaban Arze (1994) average annual incomes are only US$637 but are higher in urban areas (US$1211) than rural areas (US$577) (Bustamante *et al*., 2004).

Traditionally wheat, maize, alfalfa and potatoes have been the most important crops in the area. In Arbieto especially, higher value fruit tree crops, flowers and vegetables are now increasingly important as a result of improved irrigation. Most landholdings are individually owned and vary between 0,5 and 10 ha (average 1.2 ha per family).

The *Servicio de Agua Potable y Alcantarillado Tarata* (SEAPA-Tarata), a municipally-owned utility, supplies domestic water to Tarata town primarily from groundwater sources. Groundwater is also exploited in the surrounding rural and irrigation areas to supplement surface water for irrigation and for either private or community domestic water supply. In Tarata, the traditional separation between domestic and irrigation sectors was also challenged by the water supply utility. In 2002, SEAPA promoted additional physical and institutional infrastructure (including a new organisation, *Asociación Agropecuaria Tarata* or AGROTAR) to supply additional water to the town and surrounding peri-urban areas for urban agriculture utilising the 'domestic water' allocation from the dam. This water had proved too expensive to treat to drinking water standards because of poor quality (the reservoir suffers from high sediment loads). This development unfortunately resulted in a serious conflict with downstream irrigators, who objected to supply of water to the town for urban agriculture. This conflict is discussed in the companion paper by Bustamante *et al*. (2004).

Tiquipaya

Tiquipaya is located 11 km to the north-west of the city of Cochabamba and given its proximity to the expanding city, is a rapidly urbanising municipality. However, due to its varied topography the municipality has important contrasts in its geography over relatively short distances. To the north are rural tropical areas, in the centre are high mountains, and to the south and close to the city, the valley area. While urbanisation is strong in the valley (the urban land area increased from 3 to 40% between 1983 and 2003, and population growth now exceeds 11% per year) this part of the municipality still retains a relatively strong agricultural character based upon the traditional irrigation systems.

A series of small reservoirs in the mountain catchment harvest water for dry season irrigation in the valley, as well as being important for fishing. The rights to water in these reservoirs belong to the members of several different irrigation systems in the valley, although water is conveyed using the same main river channel. Irrigation includes highly intensive agriculture production involving flowers, dairy farming and horticultural products. The catchment area also includes storage reservoirs for domestic water supplied to the city of Cochabamba and a small hydropower scheme.

In peri-urban Tiquipaya, domestic water supplies are currently managed by a large number of relatively small community-based associations, and a larger association for the urban centre (supplying partially treated surface water). The smaller water committees typically manage piped water systems serving 50-200 families from a groundwater source. Water charges are levied upon users to fund maintenance, although new investment in systems is sometimes also funded by the municipality or other government institutions. These autonomous systems are considered to function reasonably well, water is often available 24 hours a day, and monthly water charges are low (1-1.5 Bs/month or 0.13-0.19 US$ compared to normal charges of 0.4-0.5 US$ in urban areas (Ministerio de Servicios y Otras Públicas, undated)) although performance is variable and joining fees can be high (around US$300-500). A particular strength is the high level of community participation and ownership in their operation.

However, a comprehensive water and sanitation project (the EPSA-Macoti project) currently being planned will result in major changes. Development of new water sources and water treatment works are planned to supply bulk water to the existing systems and to meet the needs of new users, and a sewerage network and treatment plant will be constructed. This project has been hugely controversial, with many concerns raised and demonstrations held, including objections to: a perceived loss of control and community involvement, the high cost of the project and associated loans, and the high water and sewerage charges that could be levied as a result. Woudstra (2003) estimated that an average volume of water supplied by the new system would cost families 11% of average income (plus a further 11% for sewerage) compared to the existing costs that are equivalent to 3.5-6.5% of income (and close to the governments advised range of 3-5%).

Methodology

Both studies reported here were detailed, small sample, case studies to investigate the household water use patterns of 'representative' case study families. However, these households were not randomly selected and the small sample sizes (a total of 11 families) do limit the conclusions that can be drawn. The survey and data collections methods employed are summarised in Table 2.

Table 2 Summary of methodologies adopted in the two study areas

	Tarata-Arbieto	Tiquipaya
Number of households	7	4
Household selection	Purposive sample of: • 3 families in irrigation area (Arbieto), • 2 families with *huertas* in Tarata (one in peri-urban area and one in town), • 2 families in Tarata without *huertas* but involved in other productive activities. In each area identified one better-off family and one poorer family based upon previous studies, local knowledge and suggestions of key contacts.	Existing sample (4 households studied detail) from earlier study by Saenz (1994) that was based on representing a range in type of agricultural production and water availability
Data collection methods	• Structured interviews with each household • Measurements of land areas • Observation of irrigation activities (and measured volumes of irrigation at field scale using flowmeters) • Observations and estimates (e.g. yields)	• Semi-structured interviews • Participant observation over extended periods including measurement and estimation of use of water in all activities • Observations and estimates (e.g. yields)
Timing of research	• Short visits from May-August 2003 (dry season with intensive irrigation)	• Extended visits Aug-Oct 2003 (dry season with intensive irrigation)
Indicators/ analysis	• Total water use by households (m^3 / lpcd) • Water abstraction from different sources (m^3 / lpcd) • Water use for different activities (m^3 / lpcd) • Costs of water from different sources (US$/$m^3$) • Returns from activities (US$) • Water productivity of activities (US$/ m^3)	• Total water use by households (m^3 / lpcd) • Water abstraction from different sources (m^3 / lpcd) • Water use for different activities (m^3 / lpcd)

There were some important differences in methodologies adopted in the two case studies. In Tarata-Arbieto, households were interviewed about water use over an annual cycle but based upon a few short visits. In Tiquipaya, extensive observations were made (water use was observed over entire days) to supplement interviews but these only focused on the period August-October 2003 which is the driest part of the year. In Tarata-Arbieto the case study families included three families in the irrigation area in Arbieto, two families with *huertas* (gardens) in the peri-urban or urban area of Tarata, and two families involved in non-agricultural productive water uses in Tarata. In each area, an attempt was made to select one poorer and one better-off family although this was only indicative. In Tiquipaya, the families

Table 3 Main characteristic of case study families

Code	Location/ type	Wealth status	House-hold size	Land area (total ha)	Main household activities	Types of water sources
1	Tarata-Arbieto	Poor	6	0.312	Irrigated agriculture *Canalero* Migration (Argentina)	Reservoir *Riadas* (storm flows) 2 dug-wells (also used for domestic)
2	Tarata-Arbieto	Poor	6	0.5	Irrigated agriculture Dam operator	Reservoir *Riadas* Well
3	Tarata-Arbieto	Better-off	3	1.5	Irrigated horticulture (peaches) Dairy cows Cheese-making Pigs	Reservoir *Riadas* 3 dug-wells 1 borewell Piped domestic water
4	Tarata-peri-urban (with huerta)	Poor	3	1.4	Irrigated agriculture Dryland agriculture Retired teacher	Reservoir Rio Lorohuachana Communal borewell *Riadas* Piped domestic water
5	Tarata-town (with huertas)	Better-off	1	0.04	Irrigated agriculture Retired agronomist	Piped domestic water (SEAPA)
6	Tarata-town	Poor	5	0	Making *chichi* Textiles Flower arranging Migration (US) Teacher	Piped domestic water (SEAPA)
7	Tarata-town	Better-off	5	0	Small restaurant	Piped domestic water (SEAPA)
8	Tiquipaya-North	-	11	0.9	Irrigated flowers, food and fodder crops Truck driver Selling flowers	*Mita* (base flow) Reservoirs (Lagum Mayu, Chankas, Piscina de Montecillos) Piped domestic water (Montecillos)
9*	Tiquipaya-Central	-	6	1	Irrigated vegetables, food crops and fodder Dairy cows Secretary of WUA Tailor Electrician	Reservoirs (Lagum Mayu) Dug-well Piped domestic water (Canarancho)
10	Tiquipaya-Central	-	4	0.16	Irrigated vegetables Carpenter Selling agricultural products Work in restaurant Pigs	Surface water (no rights) Piped domestic water (Villa Esperanza)
11	Tiquipaya-Central	-	10	3.5	Irrigated fodder Dairy cows Carpenters (2) Accountant Pigs	*Mita* (base flow) Reservoirs (Lagum Mayu, SNR1 Angostura) Waste-water mixed with spring (Cala Cala) water (40%) Piped domestic water (Chiquicollo)

Note: * In subsequent analysis, two families (9a and 9b) were considered as separate households. A third, non-agricultural household within the same plot was not studied.

studied had been involved in a previous study in 1994 and include three families in the central area and one to the north. These families had been selected at the time to cover a range of farming systems in the peri-urban areas of Tiquipaya.

In Table 3 some characteristics of the case study families are summarised, including the main activities of the household or component members, and access to water sources. In addition to

Box 1 Multiple sources and multiple uses

On a 2500m^2 plot in Tiquipaya one family [9], or arguably three related households, have an interesting pattern of water use.

- One family (9a) don't have a drinking water connection but use dug well water to wash clothes, clean the house and for cows, flowers and the huerta with peppers and medicinal plants. They use canal irrigation water to grow maize and alfalfa for the cows but use the well water for supplementary irrigation of a crop of alfalfa when the plants are stressed. They take 20 litres of drinking water per day for cooking and drinking from one of the other houses, and bath using the water from the third house.
- The second family (9b) have a drinking water connection (water they share with family 9a) but don't use the dug well. They have access to canal irrigation water too and irrigate maize.
- In the third house there lives an electrician who doesn't irrigate any crops. Although he has a house connection for drinking water now, he relied upon the dug well water to build his home since it was cheaper than using drinking water.

the main activities identified, many households have other minor sources of food or income including keeping small stock like guinea pigs and chickens. The households typically engage in a diversified set activities, and utilise multiple water sources in these (see Box 1 for example).

As discussed above, water sources in the study areas include wells, piped domestic supplies, and irrigation canals delivering surface water. Each of these main types of source is found in many different varieties. Wells may be hand-dug or drilled, private or communally owned. Domestic systems deliver both groundwater and surface water to either the household or communal taps. Irrigation canals deliver water that may be baseflow (*mita*), stored water released from reservoirs, and high river flows (*riadas*): each type of surface water typically having different allocation rights. There are other sources too: tankers deliver water in some urban areas, and domestic and industrial wastewater is utilised for irrigation.

Results and discussion

The reliance of the families upon multiple water sources is illustrated in Table 4. When calculated (only for families coded 1-5) rainfall was a key source (not harvested or stored rainwater, but the estimated amount of rainfall used by rainfed crops), even for families with access to irrigation. In fact for the families studied in Tarata in the main irrigation schemes (families 1-3), rainfall, surface water (from reservoir or *riadas*) and wells were roughly equally important by volume. Piped domestic water accounted for a small proportion of total water use, between 1 and 6% for the 'rural' and 'peri-urban' families, except for family 5 utilising this water for a *huerta* and the two families solely dependent upon domestic water in Tarata town (families 6 & 7). However as we discuss later, it is not the volume, but the reliability and convenience of use that makes piped domestic water valuable for some productive activities.

Seasonally other minor sources may also be available for these families such as springs. In Tiquipaya, family 11 mix wastewater with water from a spring (at a ratio 60:40) for irrigating alfalfa and for watering cattle. This farmer thinks that in future he will have to rely more and more upon wastewater due to declining groundwater levels associated with heavy exploitation of this resource that affects the spring flow.

Table 4 Actual use of different water sources by households

Code	Rain-fall	Surface water %			Wells	Piped domestic water	Other (e.g. waste-water)	Total use (excl. rainfall)		
	%	Reser-voir	*Mita*	*Riadas*	%	%	%	m^3/ month	m^3/ year	lpcd
1	19	39	0	5	37	0	0	-	3745	1387
2	44	37	0	16	2	0	0	-	2578	659
3	32	24	0	9	33	3	0	-	10558	6532
4	79	7	0	13	0	1	0	-	4012	761
5	42	0	0	0	0	58	0	-	216	342
6	0	0	0	0	0	100	0	-	172	94
7	0	0	0	0	0	100	0	-	138	76
8	-	77	22	0	0	1	0	3381	-	10245
9-a	-	83	14	0	2	1	0	425	-	4720
9-b	-	0	98	0	0	2	0	256	-	2843
10	-	94	0	0	0	6	0	203	-	1693
11	-	22	19	0	0	1	58	3296	-	10987

Notes: Figures for families 8-11 (Tiquipaya) were calculated during August-October, the season of highest water use. Rainfall not considered for these families. Rainfall also excluded from total use calculations.

Table 5 Use of domestic water by households

Code	Domestic water tariff	Basic use (lpcd)	Productive uses (lpcd)				Other use (lpcd)	Total use (lpcd)
			Huerta/ crops	Live-stock	Other	Total		
1	na	58.1	0	0	0	0	0	58.1
2	na	27.2	0	0	0	0	0	27.2
3	Fixed (7 Bs/ month)	48.0	38.0	178.0	0	216.0	0	264.0
4	Variable (1.2 Bs/m^3)	35.0	0	0	0	0	0	35.0
5	Variable (1.2 Bs/m^3)	59.0	289.5	0	0	289.5	0	348.5
6	Variable (1.2 Bs/m^3)	71.6	0	0	22.5	22.5	0	94.1
7	Variable (1.2 Bs/m^3)	48.0	0	0	27.5	27.5	0	75.5
8	Fixed (10 Bs/month)	53.4	28	0	60	88	0	141.4
9-a	na	42.9	19	30	0	49	14.3	106.6
9-b	Variable (1.05 Bs/m^3)	40	0	9.3	0	9.3	0	49.3
10	Variable (1.4 Bs/m^3)	44.0	12.0	12.0	3.4	27.4	5.8	77.2
11	Variable (1.5 Bs/m^3)	45.4	0	12.5	0	12.5	3.7	61.6
	Average	**47.7**	**-**	**-**	**-**	**61.8**	**2.0**	**111.5**

There is also a large range in total water use across the households that reflects both the nature of the water resources available, and the different type and scale of activities in which families are engaged. For example families 6 and 7, only with access to piped domestic water and utilising water solely for domestic use or small-scale enterprises, consumed 94 and 76 lpcd respectively. In contrast, families such as 8 and 11 with access to irrigation canal water used over 10000 litres per capital per day (lpcd) excluding rainfall.

The utilisation of domestic water supplies within each household is summarised in Table 5 (and Figure 3). Average total use of domestic water across the households was 111.5 lpcd. This amount is relatively high by developing country standards (the World Health Organisation target is 50 lpcd) but is fairly typical of Latin America. There was also a large range from a low of 27 lpcd for family 2 who use a well for domestic water and have access to several other sources for irrigation and other purposes, to a high of 349 lpcd for family 5

Box 2 Domestic water for supplementary irrigation and livestock

In Tiquipaya, family 8 pay a fixed rate for domestic water, regardless of quantity used. Sometimes, domestic water is used to supplement canal irrigation water:

- New flower seedlings need a little irrigation when transplanted but often irrigation water is not available at the optimum planting time (when seedlings are ready or labour is available) because turns are at fixed times. So in September 2003, the family used a hosepipe to take water from both own domestic tap and a neighbours (a total flow of 0.3 l/s over 8 hours equalling 8640 litres) in order to start off the crop of chrysanthemums (plot size 665 m^2). Other families in this area adopt similar practices.
- On another plot of land where the flowers (the main income of the family) are grown there is often not enough canal irrigation water to additionally irrigate a small plot of alfalfa (340 m^2) that is used as fodder for rabbits or sold to neighbours. Domestic water is often used (roughly once a month in the dry season) to complete irrigation of this plot (2.1 m^3/month)

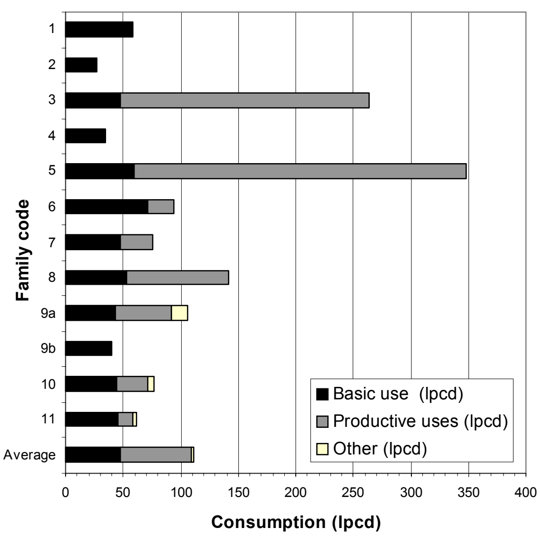
In Tarata, family 3 also pay a fixed rate for domestic water:

- A large volume of domestic water is used for watering a herd of 11 cattle that are milked for cheese production, roughly four times the amount used for 'basic' uses of the family.

where the relatively better off single resident uses significant amounts of piped domestic water to irrigate a *huerta*. On average, just over half of this 111.5 lpcd average per capita domestic water consumption (61.8 lpcd) was used for productive activities like irrigating *huertas*, watering livestock, or other enterprises like brewing *chicha* (local beer), while less than half (47.7 lpcd) was used for basic needs (drinking, washing, cooking). Some examples of productive uses of domestic water are included in Box 2.

The sample size is too small to draw conclusions regarding the impact of the type of tariff and price of water (or other factors) on the amount of domestic water used for productive activities, however tariffs are also indicated in Table 5. For both fixed and variable tariffs there are cases showing high levels of productive use. This would imply either that some people are willing to pay for extra water for productive activities, or that volumetric prices are too low to have impact on demand. However other evidence, particularly from interviews with families in Tiquipaya, suggests that volumetric tariffs and price are an important factor in the use of domestic water for productive activities, and that households with metered supplies do carefully minimise domestic water use for these activities (Box 3 and Hillion, 2003). The findings reported in Table 6 (albeit from Tarata only) support these latter observations.

Figure 3 Consumption of domestic water for basic and productive uses



The cost of domestic water in Tarata, 0.15 US$/$m^3$ (1.2 Bol/m^3), is relatively high compared to the returns calculated for many irrigated crops (partly because only field crops like maize and potatoes were studied – returns from vegetable crops should be expected to be much higher), although irrigation water for *huertas* supplied by AGROTAR (and irrigation water in Arbieto) is much cheaper and probably affordable compared to the returns possible. The use of domestic water for productive uses should therefore be expected to be confined to higher value crops and activities (including livestock), occasional use to supplement other sources especially rainfall and irrigation canal water (as we see in the examples from Tiquipaya in Box 2), or where the motives of water users are social, environmental and recreational as well as economic. In Tarata, there is a strong tradition and identity associated with the cultivation of *huertas* for example.

Table 6 Returns to activities and water productivity per household (Tarata-Arbieto only)

Code	Activity	Returns (US$)	Returns (US$/ha)	Productivity (US$/m^3)
1	Maize	78.92	631.4	1.32
	Potatoes	77.42	1238.8	0.22
2	Maize	54.42	435.36	0.14
	Potatoes	309.67	1238.68	0.48
	Wheat	49.03	392.24	0.23
3	Maize	110.45	441.8	0.31
	Peaches	14451.6	11561.3	2.42
	Cheese	2218.1*	-	22.40
4	Maize	42.5	340	0.01
	Potatoes	348.38	1393.5	0.80
	Wheat	412.9	412.9	dryland
5	Maize	55.5	1380.6	0.53
6	Restaurant	136.8*	-	-
7	Making chicha	2709.7*	-	72.26
	Textile handicrafts	458.1*	-	-
	Flower arranging	588.4*	-	-

*Figures only on enterprise and not per hectare basis
**Cost of domestic water is 0.15 US$/m^3 (1.2 Bol/m^3), cost of irrigation water is 0.04 US$/m^3 for huertas (0.28 Bol/m^3), and canal irrigation water in Arbieto about 0.001-0.002 US$/m^3 (plus labour contributions)
*** vegetable and other minor crops excluded for which per ha returns may be high.

Irrigation water is also commonly used for some domestic activities e.g. washing clothes or watering livestock. In Tiquipaya, washing clothes along irrigation canals is a common practice but non-consumptive because water is returned to the irrigation canal, albeit polluted. Generally people use irrigation water for washing clothes not to save domestic water, but because it is more practical to use the canal water which has a good flow for rinsing clothes. Irrigation canal water is also often used for irrigating flower gardens around houses in order to minimise domestic water use. Irrigation canals are also important sources of water for livestock.

As we have seen, the study families use multiple sources for multiple uses, including making productive use of domestic water even when other irrigation water sources may be available. Indeed these productive uses account for about half of domestic water consumption. What possible lessons can be drawn for the planners of infrastructure, especially new domestic water supplies? And, what changes to management rules may be required in relation to the productive uses of domestic water?

Box 3 High cost of metered domestic water restricts productive use

The female head of the family 10, also in Tiquipaya, has a small plot of vegetables that are irrigated everyday using domestic water by bucket (60 litres per day in dry season). Hosepipes are not used by the families that have to pay for domestic water by volume. A similar quantity of water (60 litres/ day) is used for her pigs. Domestic water is also important to wash the vegetables for sale. Other vegetables e.g. broccoli, leeks are grown on larger plots using canal irrigation water. However, when canal water is not available for these lands, especially leeks, she does not use domestic water because of the high cost and she says that she would rather lose the crop than incur high bills.

As mentioned earlier, as the area urbanises and population increases, planning is underway in Tiquipaya for major investments to upgrade water supply and sanitation systems. Clearly the case studies presented here do have implications for the EPSA-Macoti scheme. The relatively high demand (and potential) for the use of domestic water in productive activities in the area must be considered, planned and managed if new investments are to be sustainable. Otherwise, high per capita use of water for productive uses of water in some zones will be likely to compromise supplies in other tail-end parts of the system. Furthermore, opportunities to support livelihoods will be lost unless these demands are met. This should be considered in an integrated way that takes account of the role of domestic water systems alongside other water sources including the changing availability and access to various sources but especially irrigation canal water. Productive uses should be considered in water and sanitation social impact assessment studies, as well as in planning studies to estimate water demands and in hydraulic design.

The reality of multiple uses was recognised by the utility SEAPA in Tarata who in addition to supplying safe water from groundwater sources through the domestic network, sought to supply additional (and cheaper) water for urban and peri-urban agriculture through a system of canals. This innovative effort sets an example for other water supply utilities. It is clearly relevant in Tiquipaya where there is already an extensive system of irrigation canals, and these systems are likely to have to change in response to urbanisation processes. However, there is another important lesson from the Tarata experience. Unless water rights between irrigation and domestic water systems are clearly defined and negotiated, there is scope for considerable contestation and conflict over water resources in the middle ground between irrigation and domestic use i.e. over household level productive water uses (Bustamante *et al.*, 2004). Is there potential for similar problems in Tiquipaya?

Clearly the conflict in Tarata over water for urban and peri-urban agriculture was unique. However, evidence from water committees in Tiquipaya does suggest there is a lack of clarity around the issue of household level productive uses of water that inhibits proper provision of water to support these activities. Water committee representatives often talk about the use of the water supplied by their systems for 'domestic' purposes. These domestic uses clearly include drinking, cooking, and washing clothes but many water committees also cite the irrigation of homestead gardens as domestic use. In a number of communities the water supplied is used for livestock, and in one case it was said that if the water was not used for this purpose too then the monthly water use would be so low that the committee would not bother to collect the payments. Several water committees have written regulations that state the purposes for which domestic water may and may not be used. These regulations sometimes say that water may not be used in construction activities (or only at an additional cost), for washing vehicles, and that water may not be sold or given to neighbours. Often these regulations mention that domestic water may not be used for agricultural purposes, and this is meant to mean the irrigation of larger plots. However, regulations are not clear as to the scale at which irrigation of a plot or homestead garden becomes a prohibited agricultural activity.

Summary and conclusions

Although findings of the studies reported here are only indicative and need to be followed up by larger scale research studies, a number of preliminary conclusions can be made:

- The need for multiple uses was recognised by the utility SEAPA in Tarata who in addition to supplying safe water from groundwater sources through the domestic network, sought to supply additional (and cheaper) water for urban and peri-urban agriculture through a system of canals. Similarly, the designers of the proposed EPSA-Macoti water and sanitation system in Tiquipaya should take account of the relatively high demand (and potential) for the use of domestic water for productive activities in Tiquipaya and the need to plan in an integrated way for multiple uses from multiple sources. Otherwise, opportunities to support livelihoods will be lost and high per capita use of water for productive activities may compromise supplies in other tail-end parts of the system.

- At the household level, a significant proportion (roughly half) of so-called 'domestic' water supplied in Tarata and Tiquipaya was used by the case study families for productive activities: including irrigation of *huertas*, watering livestock or other enterprises. Equally, irrigation water is used, at times, for domestic purposes.
- In some cases domestic water provides the sole source and makes small-scale irrigation of *huertas* or other enterprises possible. More often domestic water provides an important supplementary source and reduces risks in irrigated cropping where canal water is inadequate or unreliable. In general, non-domestic sources provided a far greater quantity of water for productive purposes, but the strengths of domestic water supplies are their availability (often 24 hours a day), reliability, and convenience.

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