PLANNING FOR MULTIPLE USES OF WATER: LIVELIHOOD ACTIVITIES AND HOUSEHOLD WATER CONSUMPTION IN PERI-URBAN COCHABAMBA, BOLIVIA

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Abstract - This paper presents two methodologies to assess livelihood activities and water use as part of the planning of water supply projects. A case study from peri-urban Tiquipaya, close to the city of Cochabamba in Bolivia, illustrates results from both the rapid and more detailed methodologies presented. The main findings of the case study are that the productive uses of domestic water supplies, particularly irrigating small gardens (*huertas*) and watering livestock appear to have been underestimated to date, both in their importance for the livelihoods of households in Tiquipaya and in patterns of water use. Currently, water supplies are mainly provided by small locally-managed groundwater-based systems, although there is a contested plan to move towards more centrally-planned systems. It is concluded that the future development of water supply systems in the area is more likely to be sustainable and to meet local needs if productive uses of water at the household level are considered at the planning stage: these activities being particularly dependent upon the availability and cost of domestic water supplies.

Keywords - Multiple uses; water supply; groundwater; irrigation; peri-urban; agriculture; Bolivia.

INTRODUCTION

The planning of most domestic water supply projects in Latin America is still largely premised upon the quest for improved health. The assumption is that a closer, more plentiful and critically, better quality, water supply will reduce the transmission of disease. This approach is now widely challenged as being both too simplistic, and ignoring the many other benefits of improved water supplies. On the one hand, research shows that having easy access to a sufficient quantity of water, access to sanitation, and good hygiene behaviour, can be at least as important as water quality in leading to improved health (Howard and Bartram, undated). On the other hand, people

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frequently express a preference for low cost and high volume water supplies over the need for piped water quality of the highest standard. A cheap, plentiful water supply is especially important where people engage in small-scale productive uses of water such as garden irrigation, and keeping livestock. The challenge facing design engineers in these situations is how to meet accepted national and international water quality standards, while continuing to supply sufficient water for small-scale productive uses at an acceptable cost?

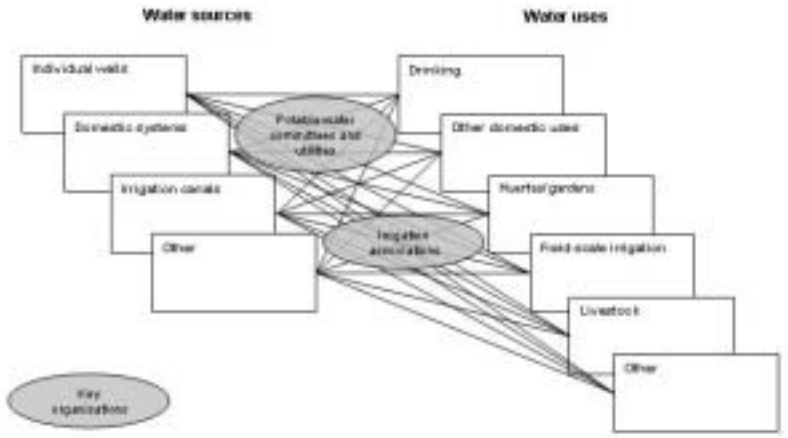

Figure 1 - Multiple water sources and uses.

In most situations, this challenge is avoided by planners and as a consequence, communities get low volume-high quality (as long as the treatment facilities can be adequately operated and maintained) water supply schemes from the design manual that do not adequately meet their multiple needs for water use. This results in over-loading and failure of systems where people necessarily 'persist' with high consumption productive activities. Where control measures (such as the introduction of metering, charging for water based upon volumetric use and the raising of water fees) are effective in reducing demand, people lose a set of potential opportunities to grow food or earn income. Small-scale productive water uses can support livelihoods (see for example Moriarty, 2004).

An emerging solution to this problem is to plan water supply projects based upon local needs and an integrated approach to the use of water from multiple sources for multiple purposes (Figura 1). Consistent with this broader and more demand-responsive approach to water supply development, we present in this paper two simple methodologies that can be used as part of water supply planning in areas where small-scale productive uses of water might be important. Firstly, a livelihood activities and water use survey that can be used to rapidly assess patterns of household water use, and second, a more in-depth household-based assessment of water uses and sources. The use of the findings of these surveys to develop recommendations for water supply planning is

explored using the example of peri-urban Cochabamba, Bolivia. This is an area where major new investment in water and sanitation infrastructure is planned.

STUDY AREA AND BACKGROUND

The city of Cochabamba in central Bolivia lies at the edge of the Andes and within the upper part of the Amazon basin (Figure 2). The climate is mild but relatively dry, and scarce water supplies are often contested between the rapidly growing city and the surrounding agricultural communities. The city is surrounded by productive valleys that even in modern times remain bread-baskets for the country as a whole. One of these agriculturally productive areas, where this study focused, is the Municipality of Tiquipaya on the peri-urban fringes of the city.

The centre of Tiquipaya is 11 km to the north-west of the city of Cochabamba. 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. Urbanisation is strong in the valley: the urban land area increased from 3 to 40% between 1983 and 2003, and population growth is high. The municipality had a population of 37,800 in 2001, and according to census data population growth is over 11% per year (INE, 2001). Despite such population growth, this ‘peri-urban’ 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 (there are also rights to dry season and rainy season river flows) belong to the members of six main irrigation systems in the valley (around 2500 farmers), although water is conveyed using the same main river channel. Irrigation supports generally intensive agriculture including production of flowers, horticultural products and dairy farming (based upon cultivation of alfalfa). Additional irrigation water is provided by a canal from the Angostura reservoir to the south-east of Cochabamba. The catchment area also includes storage reservoirs for domestic water supplied to the city of Cochabamba and a small hydropower scheme.

Figure 2 - Location of study area

Pressures on available water resources in the valley have gradually built up between water users. Since the 1970s groundwater has been progressively developed, and there are now concerns that groundwater levels are declining and the flow of springs is reducing. Pollution of groundwater is a further concern. As domestic water demands have increased in the valley, and in Cochabamba, competition for scarce water resources has been exacerbated and there is increasing potential for conflict between different stakeholders including irrigators, municipalities, locally-managed domestic water systems, and urban domestic water utilities. Development policies and projects have considerable potential to clash with the existing domestic and irrigation systems that are based upon local norms and rules.

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 (approximately 85% systems utilise wells or springs according to van der Meer, (2004) based upon a survey of 38 out of 90 systems in Tiquipaya and neighbouring Colcapirhua), although some systems also share surface water sources with the holders of irrigation water rights. These locally-managed systems are considered to function reasonably well: there is a high level of community participation and ownership in their operation, water is often available 24 hours a day, water quality of groundwater sources in Tiquipaya is relatively good (but not in neighbouring Colcapirhua where there are problems with iron, manganese and microbial contamination) and monthly water charges are low (averaging 1 Bs/m^3 or 0.13 US$/$m^3$ compared to normal charges of 0.4-0.5 US$/$m^3$ in urban areas

(Ministerio de Servicios y Otras Públicas, undated)). However, joining fees for new connections are high (generally US$300-400).

However, a comprehensive water and sanitation project, *Empresa Proveedora de Servicios de Agua Potable y Alcantarillado* from the *Mancomunidad Municipal Tiquipaya-Colcapirhua* (EPSA-Macoti) currently being planned will result in major changes. Development of new water sources and water treatment works are planned to supply bulk water (initially from new deep wells and potentially later from a major regional project to develop new surface water resources for domestic use, irrigation and hydropower) to the existing systems and to meet the needs of new users, and a sewerage network and treatment plant will be constructed. The EPSA-Macoti project has been hugely controversial, with many concerns raised and demonstrations held, including local objections to: a lack of information and consultation, a perceived loss of control and community involvement, the high cost of the project and associated loans, concerns about proposals that involved privatisation, and the high water and sewerage charges that could be levied as a result.

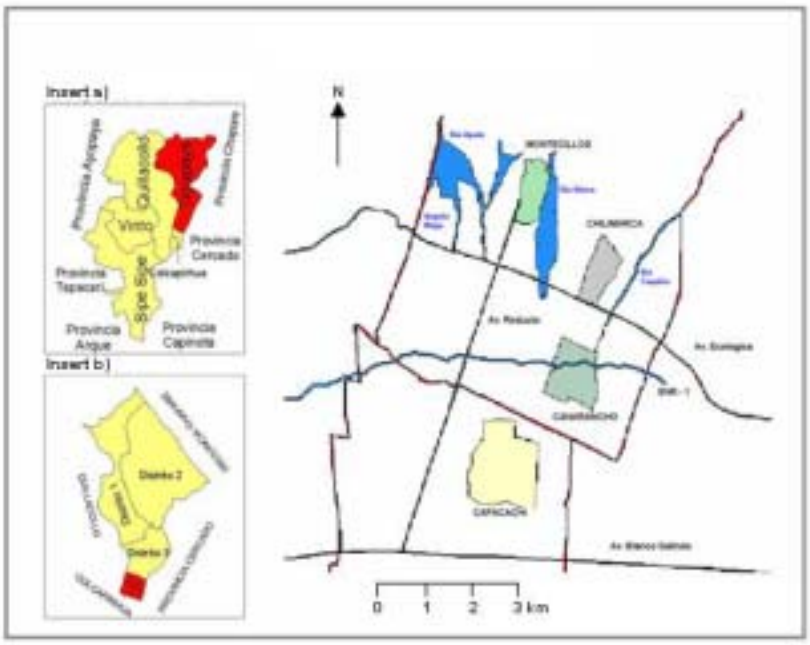

Figure 3 - Location of four study areas within the valley area of Tiquipaya (main map), municipalities within Quillacollo Province (insert a) and location of valley area within Tiquipaya municipality (insert b)

Design parameters for the EPSA-Macoti, according to project documents, include drinking water quality (the project includes a water treatment plant) and a volume of supply equivalent to 125 lpcd initially, but rising to 145 lpcd over a 20 year period. The volume of 125 lpcd was based upon domestic water use equivalent to 105 lpcd, commercial water use equivalent to 10 lpcd, and industrial water use equivalent to 10 lpcd. These figures appear to be based upon domestic needs

and ‘formal’ commercial and industrial water use such as factories, hospitals, and restaurants. The authors of this article are not aware of any evidence of whether multiple uses of water at the household level were considered in the planning or design, and how the volume of 105 lpcd was calculated. Was this figure based only upon estimation of ‘basic’ needs or did it also allow for water use in small-scale productive activities such as gardening and keeping animals? A concern must be that the design volume potentially underestimates household water needs, especially for productive uses, and that will be provided which is too costly to be used for these activities. Furthermore, a design volume of only 80 lpcd has been mentioned by the planners in meetings.

In fact, since the project will only supply bulk water in the areas served by existing locally-managed water supply systems it is unclear how future water supplies will develop. The cost of this bulk supply, initially based upon the proposed new groundwater sources is a source of major uncertainty in the future of the project and locally-managed systems. Verbal proposals suggest a bulk water charge of 1 Bolivano per m^3 (0.13 US$/$m^3$) which is approximately equal to the charge made at the moment by locally-managed water supply systems to their consumers. In the absence of any agreements or contracts, it remains unclear how much water will eventually be supplied from the centrally-controlled groundwater sources and the locally-managed sources.

METHODOLOGY

The study involved two household surveys: 1) a rapid assessment of livelihood activities and water use with a sample of 70 families, and 2) detailed case-studies of water use with a sample of 17 families.

Selection of study areas and household samples

The study focused on four different areas in Tiquipaya (see Box 1 and Figura 3). These areas were selected using aerial photography to cover a representative range in the main current patterns of land (and water) use. They included areas where land use is principally: 1) urban, 2) horticulture, 3) diversified agricultural production, and 4) livestock farming for milk production. Each area was about 60-80 ha in extent, and contained between 120-230 households.

Initially, each study area was mapped using aerial photographs to identify all the households in the study area. Households were subsequently classified according to their type of house (using a crude rapid assessment into categories of rich, medium, and poor) for urban households (households without fields), and according to the cropping pattern and intensity of land use for farmer households (households with fields). A stratified sample of 15% of the three dominant type of households in each area was then selected. This was a total of 70 households, although only 64

surveys were complete and used subsequently. For the more detailed survey a sub-sample of 3-5 households was selected from the dominant types of households in each zone, and willingness of households to participate further.

Box 1 Characteristics of study areas within Tiquipaya

Chillimarca: a relatively urbanised area (39% urban land use) in the northern part of Tiquipaya, where most of the population are migrants engaged in the 'urban-economy': as public employees in the city, service-sector workers (drivers, house-builders etc.) and traders. However, some neighbourhoods are dominated by the mansions of very rich residents. Several water committees provide domestic water, but only a little irrigation water reaches the area.

Villa Esperanza - Canarancho: located in the middle part of Tiquipaya, this area has diversified agricultural production where part of the population are still farming-oriented, but increasingly involved in other activities (11% urban). Farming families live together with newcomers who are primarily engaged in other economic activities. Both domestic water supply and irrigation systems deliver water to the area. The area is a zone of natural groundwater discharge area with several springs.

Capacachi: in the southern part of Tiquipaya this area is dedicated mainly to fodder cultivation and livestock farming for milk production, however the farming area is being encroached by several new neighbourhoods (14% urban). Because of the distance to the main water intake for irrigation, poor water distribution does not allow farmers to further intensify agricultural production. Several groundwater supply systems also provide water for the peri-urban neighbourhoods.

Montecillo: in the north-western part of Tiquipaya this is an area of very intensive production, mainly horticulture and floriculture, taking advantage of the situation in the upper zone of the valley and the proximity to the main irrigation water intake (6% urban). Many of the population are farmers, but with smaller plots than in the other areas. No groundwater is used because of the location but there is relatively high surface water availability.

Rapid assessment of livelihood activities and water use

The rapid assessment of livelihood activities and water use could be undertaken in about 30 -60 minutes for each household, after the team of two interviewers had been trained and gained experience. The methodology is summarised in Box 2. A rapid initial survey was important in order to cover a larger sample of respondents, and because respondents both cannot often spare much time away from their other activities and in the current context are relatively suspicious of numerous surveys and studies that have been undertaken in the area. After the rapid assessment, each respondent was asked whether they would be willing to participate in a further more detailed survey, and understanding the questions and approach, most respondents were willing to participate further.

Box 2 Checklist used for rapid assessment of livelihood activities and water use

1. Ask the respondent to list all of the productive activities (defined as activities that produce food or income) in which the household (all members) are involved. List each activity on a card (symbols may be preferred where respondents are not literate), for example, potato crop, growing flowers, keeping cows, vegetable garden, making beer, operating a taxi, son working in factory etc. A key decision is whether to ask respondents to break down activities into lower categories. For example, agriculture may give insufficient detail on the families' activities, whereas listing every crop grown provides too much detail.
2. Ask the respondent to order the cards listing the productive activities in order of importance to the household.
3. Then for each productive activity, ask the respondent to describe how much water (from any source) is required. Indicate by each card the response using stones or symbols, for example, 0 no water, 1 little water, 2 significant water, 3 a lot of water.
4. Then for each productive activity (where the reply to question 3 was not 0 i.e. no water), ask the respondent to describe which water sources are used for each activity (for example, domestic supply, own well, rainfall, irrigation canal, wastewater, other (specified) etc). Ask and label sources as either primary (p), secondary (s) or occasional (o) sources. Prompt to ensure that every source for each activity is captured. Mark the replies on the card using symbols.
5. Then ask any follow-up questions. In this survey, these were 1) how has the availability of water for productive activities changed over the past 10 years, and 2) how do you think the availability of water for these productive activities will change in the next 10 years?
6. Transfer the data from the cards to a recording sheet along with answers to questions, and the name, location, and size of the household, together with a subjective assessment of wealth status.

Detailed case-studies of water use

The detailed case studies with 3-5 households in each zone took about one day for each households (with two interviewers) and a further half day for each family to return and validate the analysed information, and to fill gaps. The methodology used is summarised in Box 3.

Box 3 Checklist used for detailed case studies of water use

1. What are the main characteristics of the household: size of household, ages of family members?
2. To validate information already collected from the rapid assessment, what are the main livelihood activities of the households?
3. For agricultural activities what are the crop types cultivated during the year (using a seasonal calendar)?
4. How much water is used for each activity and from which water sources is water utilised? Assessment is based upon recall using a monthly calendar in any case. Care should be taken to separate both water uses and water sources using the following classification:
5. What are the benefits derived from each activity? Include production that is for home consumption and sale. Calculate benefits on both a household basis, per unit land area, and per unit volume of water consumed? The economic benefits of different water-consuming activities were based upon Molden & Sakthivadivel (1999).

Water uses:

- Domestic: Domestic use was separated between various 'basic domestic uses' (drinking, cooking, personal sanitation (washing and toilet), washing utensils/ kitchen water use, washing clothes, and house cleaning), 'productive uses' in and around the household (including irrigation of gardens (*huertas*), watering of livestock and some other small-scale enterprises like making beer (*chicha*) and small restaurants) and 'other' uses (such as washing cars, flower gardens, swimming pools etc).
- Field irrigation: field-irrigation is relatively easy to distinguish in the study area from irrigation of gardens. Plots are larger, crops more uniform, and usually fields are further away from the house.

Water sources:

- *Domestic:* As used elsewhere in this paper, domestic water was considered as water that is supplied through a piped network to multiple households. Water is paid for either on a monthly or volumetric basis.
- *Wells*: These include dug-wells and drilled borewells. In some areas wells are artesian.
- *Springs*: Springs are found mainly in central area of Tiquipaya.
- *Reservoirs*: Reservoirs both within and outside (Lake Angostura) the local catchment area supply water by canal. There are carefully defined water rights based traditional 'uses and customs'.
- *Mitas:* Base flows of the Rio Khora which flows through Tiquipaya, and specific rights are attached to use of this water.
- *Riadas*: High flows of the Rio Khora, again with specific water use rights.
- *Tankers*: Water tankers are relied upon to deliver water in some areas with limited infrastructure.

RESULTS AND DISCUSSION

Survey of livelihood activities and water use

The results of the rapid assessment of livelihood activities and water use survey show that in Tiquipaya: families have very diverse livelihoods i.e. there are multiple livelihood activities within households; and that livelihood activities are based upon access to a wide-range of possible water sources. These patterns are discussed in the following two sections.

Livelihood activities

Agriculture (here we refer to field-scale cropping) was the major economic activity, cited as the main source of income, food or other benefits by 34% households. In fact, of the 666 households within the four areas, 270 households (or 41%) had 'fields' (Table 1). Other common activities listed as the premier activities of households included building (13%), driving (11%), petty trade (8%) and dairy farming (8%).

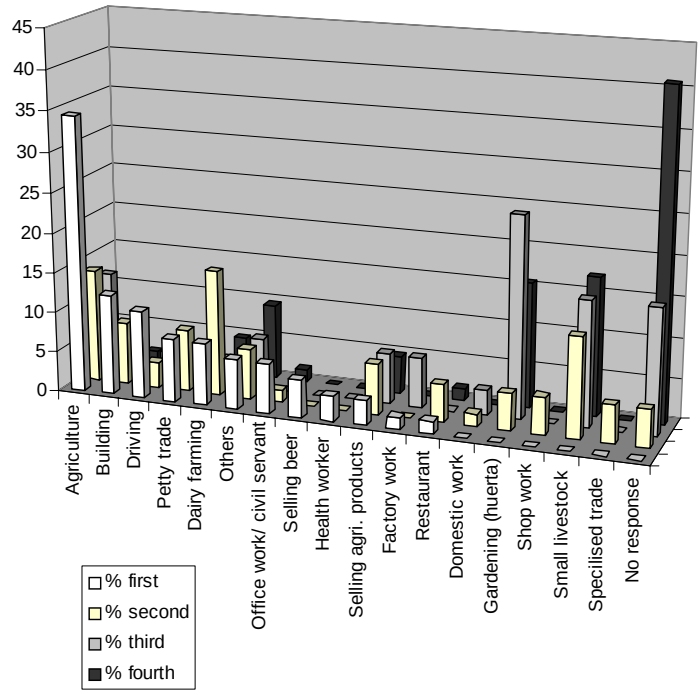

Figure 4 - Livelihood activities of households.

As well as field-scale agriculture, usually irrigated cropping, figure 4 shows that raising animals (small livestock like sheep and pigs; and cows for dairy farming), and cultivated small gardens (*huertas*) are important. Not usually as the main sources of household income or food, but rather as activities of second, third or fourth importance. Small livestock and gardening were never the main household activity (dairy farming was for 8% households), but dairy farming, small

livestock and gardening represented the second activity of 16, 13 and 5% of households respectively. These same activities represented the third most important activity for 3, 16 and 25% households, and the fourth most important activity for 5, 17 and 16% respectively. At this level (as the second, third or fourth in importance), these activities are amongst the most common. Also, of the 666 households in the four areas, 235 households (or 35 %) had *huertas*. As we see later, these small-scale agricultural activities in and around the household tend to use relatively large quantities of water (less than field scale irrigation but more than other livelihood activities), and from different water sources to field-scale irrigation.

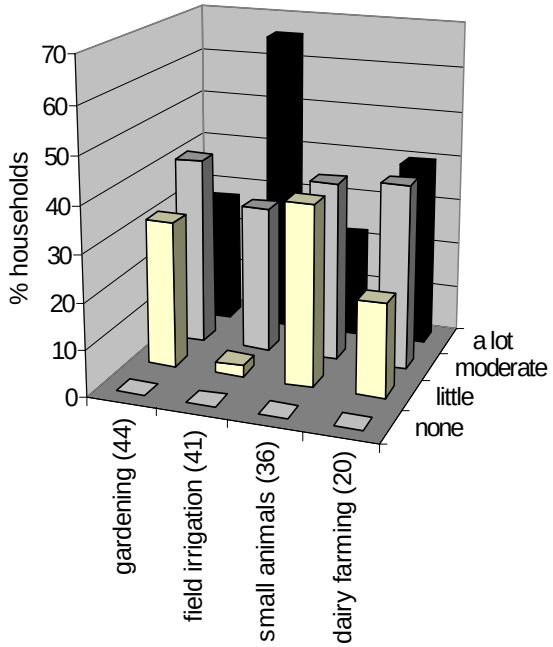

Figure 5 - Levels of water use in major water consuming livelihood activities (sample size in brackets after each activity).

It is not only 'farmers' (people whose main activity is field-scale agriculture) who are involved in the smaller-scale productive uses of water. 'Non-farming' families (mainly people who have migrated to Tiquipaya) are also engaged in these smaller-scale activities, mainly cultivating *huertas* and small animals, and usually between 3 to 5 economic activities per household were identified within this group. This is possibly due to the relatively large plot sizes which make it possible to have *huertas* or to keep small animals, the availability of reliable water sources, and the need to diversify livelihood activities.

Water use and sources

Livelihood activities which were assessed to consume significant quantities of water were (in order of sample size): gardening, field-scale agriculture, keeping small animals, and dairy farming.

figure 5 illustrates the approximate levels of water use required by each of these activities, as assessed by survey respondents. As may be expected, field-scale irrigated agriculture consumed the most water with 66% respondents engaged in this activity (64% of the 64 households surveyed were involved in this activity) saying this needs 'a lot' of water. However, of particular interest is the relative high water needs for household-level activities: gardening (69% households surveyed involved), keeping small animals (56% households involved), and dairy farming (31% households involved). Other activities involving lesser water consumption and fewer households were cheese making, and running small restaurants.

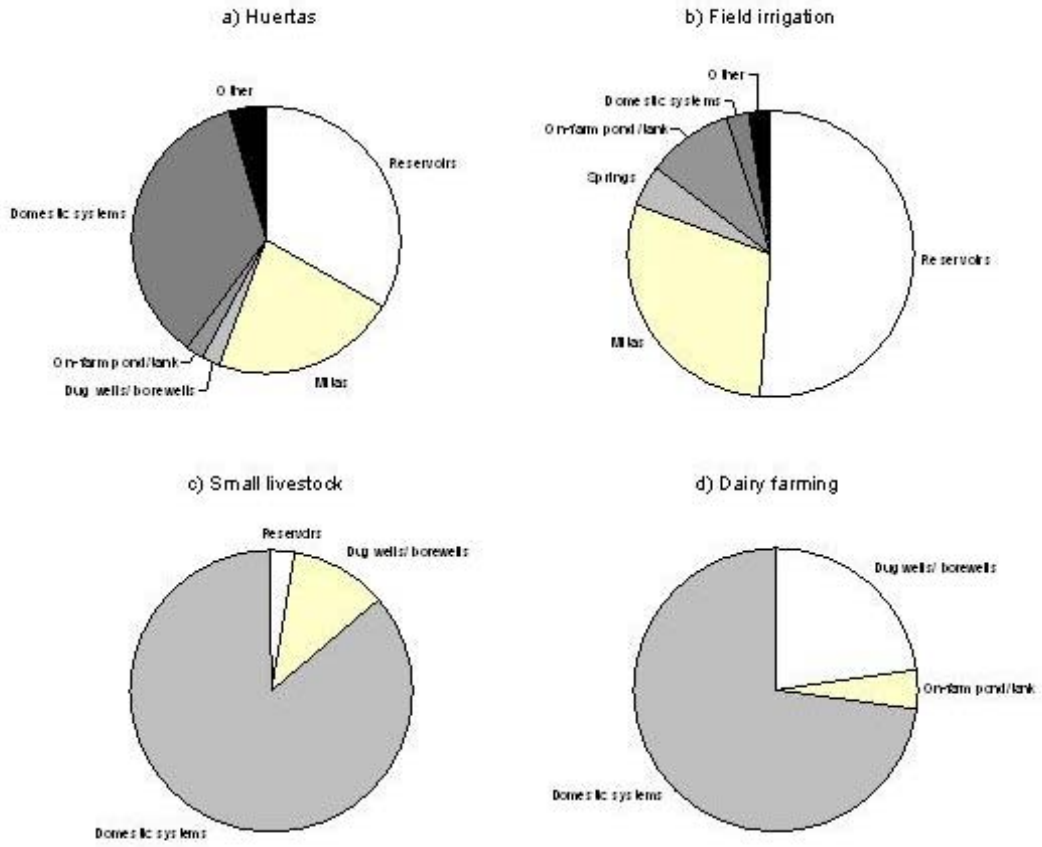

Figure 6 - Principal sources of water for major water consuming activities

Figure 6 shows the major sources of water for the major water consuming livelihood activities. Irrigation of huertas and field-irrigation is based upon quite a diverse set of principal water sources. The major sources for *huertas* being domestic systems (36%), reservoirs (33%) and base flow *(mitas)* (22%), while minor sources include wells and in one case, tankered water. Reservoirs, both from the upstream catchment and Lake Angostura outside the catchment (51%) and baseflow *(mitas)* (29%) are the major sources for field-irrigation although springs and other

minor sources are also important. The patterns of water use for livestock are different. Both small livestock and dairy animals are principally dependent upon the domestic water supply (86% and 73% households respectively) while wells are also the principal source for a significant number of other households.

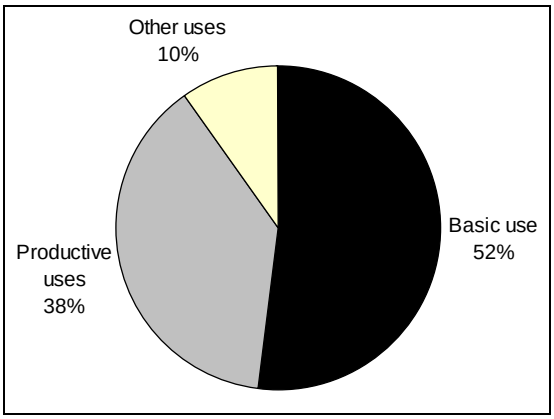

Figure 7 - Average consumption of domestic water for basic, productive and other uses

As we see, domestic water supplies are a major source of irrigation water for *huertas*, and for watering of large and small animals domestic water supplies are the main source. Domestic water supplies thus have a crucial role in productive activities at the household level. The impact of future domestic water supply investments and institutional change that may affect the availability and cost of domestic water supply should therefore be expected to include (probably negative due to expected higher water costs) impacts upon small-scale agricultural activities and the contribution of these activities to household incomes and food security.

Detailed assessment of water use

Some basic characteristics of the 17 households that were selected for detailed study are shown in Table 2.

Domestic water consumption

Total consumption of domestic water averaged 140 lpcd (Table 3) where 52% was used for basic needs, 38% for productive activities, and 10% for other uses (figure 7). Domestic water use at this level is well in excess of basic international minimum standards (which typically tend to be in the range 20-50 lpcd), and in line with other studies elsewhere in Tiquipaya that also tend to indicate relatively high domestic water consumption. Woudstra (2003) studied domestic water consumption, at the system level for four water supply systems in Tiquipaya and neighbouring Colcapirhua (Morococala, Santa Isabel, Huanuni, and Holanda), and found average consumption

was 94, 94, 204 and 110 lpcd respectively, or an average of 125 lpcd across the four systems (assuming average household size of 4.1 persons). In a much small study of only four households in Tiquipaya, Hillion (2003, see also Bustamante *et al*., 2004a) reported domestic water use averaging 74 lpcd.

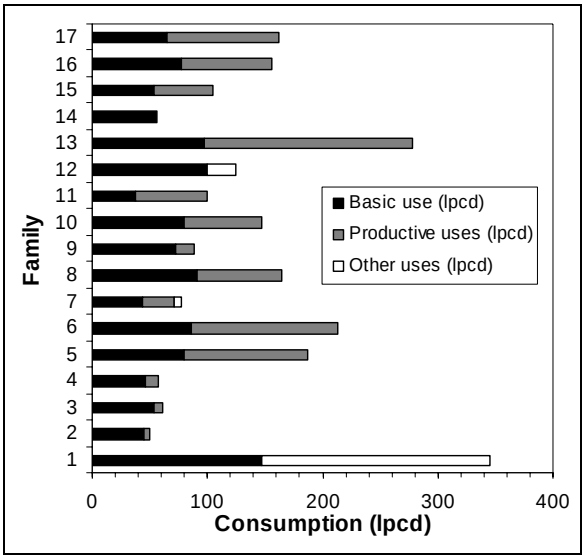

Figure 8 - Consumption of domestic water for basic, productive and other uses.

Figure 8 illustrates the high levels of variation in water use between the families surveyed. Whereas, productive and total use is extremely variable across the sample of households, the use of domestic water for basic uses is more consistent.

The basic use of domestic water supplies by these families is summarised in

Table 4. On average, households consumed 72 lpcd for basic needs (equivalent to 52% of total domestic use), of which 42 lpcd (or 57%) was used for washing and personal sanitation. All of the families had in-house piped water supplies with shower facilities, and also all had flush toilets

Productive uses of domestic water are summarised in Table 5. On average, households consumed 54 lpcd (or 38% of total domestic use) of water for these activities. Keeping livestock (11 of the 17 families) used the most water (56% of productive use), followed by *huertas* (10 of the 17 families and 35% of productive use) (figure 8). Two families also used some domestic water to partially irrigate field-scale crops.

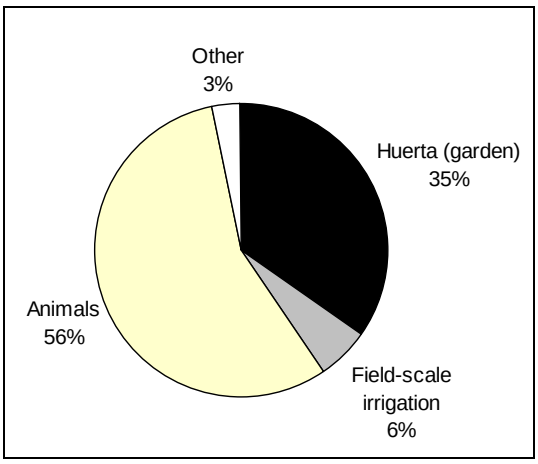

Figure 9 - Productive uses of domestic water.

There do appear to be variations across Tiquipaya, although the sample size within each of the four study areas was very small. As shown in figure 9, there was relatively little productive use of domestic water in the most urbanised area of Chillimarca, but here there was a high level of other water use, albeit biased by the much higher water use for irrigating a garden and for filling the swimming pool of one well-off family.

Given the relatively high levels of water use, available at a low price (often based upon a monthly rather than volumetric charge) and with a high level of reliability, it is perhaps not surprising that proposals to develop new water supply infrastructure in Tiquipaya have been strongly contested. Although joining fees are high for new consumers, and not all areas may be served by existing systems, the performance of the water supply service is better than that available in most other metropolitan areas in Bolivia. And the systems provide sufficient water for productive activities in and around the household. This may not remain the case in future.

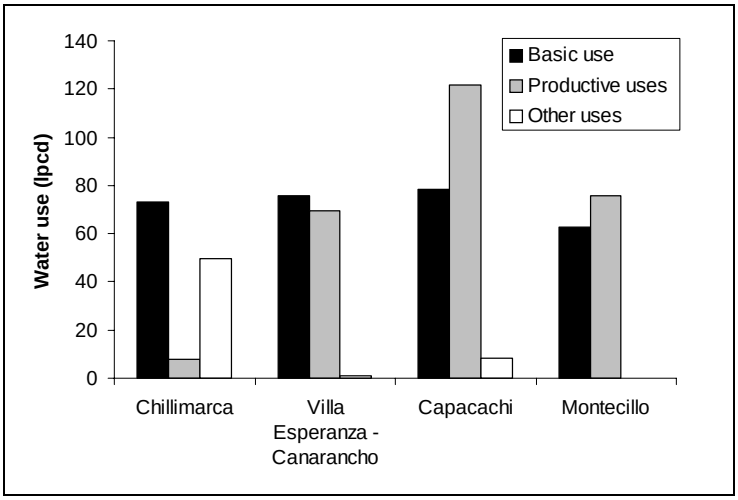

Figure 10 - Variations in domestic water use across the four study areas.

Currently the locally-managed water supply systems provide a relatively high quality, high quantity and low cost water supply service, of which an important benefit appears to be the potential for households to utilise domestic water supplies for productive activities. As Tiquipaya urbanises and develops, future water supply policies and investments are likely to result in increases in the availability and the unit cost of domestic water. Whether household-level productive activities like gardening and keeping livestock continue to thrive will depend to a large extent upon whether domestic water supplies continue to be affordable for these activities.

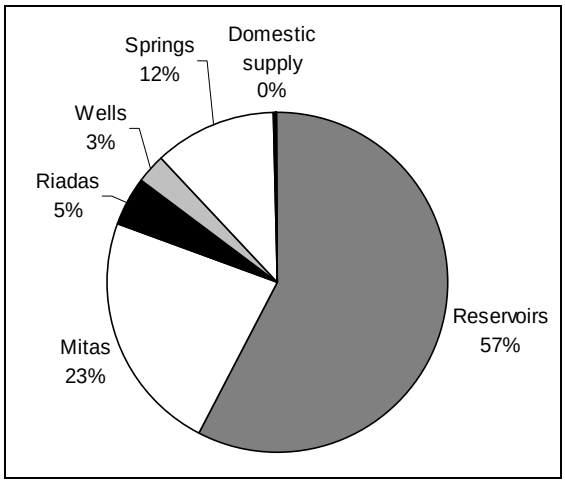

Figure 11 - Sources of water for field-scale irrigation.

Field-scale irrigation

Out of the 17 families surveyed, 14 families farmed irrigated agricultural land. The average annual cultivated area was 1.1 ha per family, although actual irrigated landholdings are slightly lesser in extent (0.9 ha per family), and more than one crop is grown per year. Here, we focus on this field-scale irrigation and exclude cultivation of smaller gardens or *huertas*.

Irrigation water use from different sources is summarised in Table 6. Total irrigation use for the families averaged 8699 m^3 which is equivalent to 767 mm depth of water across the irrigated land area. Converted to units which are comparable to the figures for domestic water use, average field-scale irrigation water use was 4205 lpcd, approximately 30 times greater than the average domestic water consumption on a per capita basis. Most of the irrigation water was derived from the reservoirs (57%), followed by base flow (*mitas*) (23%), springs (12%), high river flows (5%) and wells (3%) (figure 11). Negligible quantities of domestic water were used for field scale irrigation, although this very limited use can be important at times, for example, in helping to ensure germination of crops when irrigation water is not available (Bustamante *et al*., 2004a).

Although such large volumes of irrigation water were used by families, domestic water supplies are still used for small-scale productive activities because they are much more readily

available. Unlike irrigation water, which may only be available seasonally and 4-5 times a year, domestic water supplies are often reliably available for 24 hours a day.

SUMMARY AND CONCLUSIONS

The main findings of the study were that:

- a combined rapid assessment of livelihood activities and water use and a more detailed survey of water use was an effective way to characterise patterns of water use at the household level, and to collect information on small-scale productive uses of water at that are frequently overlooked.
- a survey of livelihood activities across 70 households in Tiquipaya showed that household level productive uses of water are important, not generally for the main livelihood activities within the household (this tended to be field-scale agriculture or other activities) but rather as activities of second, third or fourth importance within a diversified set of household livelihood activities.
- access to multiple sources of water is a crucial enabling factor in the livelihood activities of households in Tiquipaya. Families tend to access multiple sources both for different activities and for the same activities at different times in the year.
- a more detailed survey of 19 households in Tiquipaya showed that total domestic water consumption was relatively high (on average 140 lpcd) and that a large proportion of domestic water was used for productive activities (on average 54 lpcd or 38% of the total use).
- the most common supplementary livelihood activities in Tiquipaya, gardening (*huertas*) and keeping livestock (small livestock and dairy animals) depended to a large extent upon domestic water supplies, because of their ease of availability and reliability, and hence the contribution of these activities to household incomes and food security is likely to be significantly affected by changes in the availability and cost of domestic water supplies.
- while the families surveyed in the detailed study consumed on average 30 times more water for field-scale irrigation than their domestic water consumption, water for field irrigation is only available infrequently during the year. Field irrigation water was derived from various sources, mainly reservoirs and base flows, but also high river flows, springs and wells.
- currently the locally-managed domestic water supply systems provide a relatively high quality, high quantity and low cost water supply service, of which an important benefit appears to be the potential for households to utilise domestic water supplies for productive activities. As Tiquipaya urbanises and develops, future water supply policies and investments are likely to result in increases in the availability and the unit cost of domestic

water. Whether household-level productive activities like gardening and keeping livestock continue to thrive will depend to a large extent upon whether domestic water supplies continue to be affordable for these activities.

ACKNOWLEDGEMENTS

The authors would like to thank all the households from Tiquipaya that participated in the research presented here. The studies were financially supported by Centro-AGUA and the 'Facilitating negotiations over land and water management in peri-urban Latin American catchments' (NEGOWAT) Project (www.negowat.org) financed by the European Commission and the United Kingdom's Department for International Development (ICA-2002-10061 and Project R8324). The research presented here was also undertaken as part of the doctorate studies of Alfredo Duran at the Wageningen University and Research Centre, the Netherlands, and the project 'Multiple use systems' of the CGIAR Challenge Programme – Water and Food. Nicholas Faysse and Rocio Bustamante provided helpful comments on an early draft of the paper.

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Table 1 - Number of households within study areas, and number of households with *huertas* and fields

	Chillimarca	**Canarancho**	**Capacachi**	**Montecillo**	**Total**
Total number of households	190	130	226	120	666
Number of households with 'fields' (%)	45 (24%)	100 (77%)	42 (19%)	83 (69%)	270 (41%)
Number of households with '*huertas*' (%)	60 (32%)	60 (46%)	25 (11%)	90 (75%)	235 (35%)

Table 2 - Households selected for detailed assessment of water use

Code	Family	Area	No. of people	Domestic water tariff	Principal livelihood activities	Sources of water
1	Residencia	Chillimarca	6	Volumetric (1,50 Bs/m3)	Gerente Emcogas Rentista Oficinista	Conexión dom. Pozo perforado
2	Rocha	Chillimarca	4	Volumetric (2,00 Bs/m3)	Albañil Agricultura Fabril Jornalero Lavado de ropa Crianza de animales menores Comercio	Conexión domiciliaria Acequias Camión cisterna Mita Chuta qawa Lagun Mayu
3	Rodríguez	Chillimarca	13	1) Fixed (7,00 Bs/m3); 2) Volumetric (2,00 Bs/m3)	Agricultura Huerto Albañil Crianza de ganado mayor Crianza de animales menores Reventa y/o rescate de productos agropecuarios Magisterio	Conexión dom. I Conexión dom. II Acequias Camión cisterna Mita Chuta qawa Lagun Mayu
4	Zurita	Chillimarca	10	Volumetric (1,60 Bs/m3)	Costura Huerto	Conexión domiciliaria
5	Aguilar	Villa Esperanza - Canarancho	5	Volumetric (1,00 Bs/m3)	Agricultura Reventa y/o rescate de productos agropecuarios Crianza de animales menores y ganado menor Producción y/o venta de quesillo Huerto	Angostura Lagun Mayu Riadas Conexión dom
6	Amurrio	Villa Esperanza - Canarancho	3	Volumetric (4,00 Bs/m3)	Agricultura Crianza de ganado mayor Estudiante Tec. Electricista Huerto	Lagun Mayu Machu Mita Pozo Conexión dom
7	Claros	Villa Esperanza - Canarancho	4	Volumetric (1,40 Bs/m3)	Agricultura Reventa y/o rescate de productos agropecuarios Crianza de animales menores y ganado menor Peinadora Chofer	Pozo Conexión dom
8	Ledezma	Villa Esperanza - Canarancho	7	Stepped volumetric (1,00 Bs/m3; then 2,00 Bs/m3 from 10-20 m3, and 5,00 Bs/m3 >20m3)	Crianza de ganado mayor Agricultura Huerto Tec. Agrónomo	Angostura Lagun Mayu Machu Mita Riadas Pozo excavado Conexión dom

9	López	Villa Esperanza - Canarancho	6	Stepped volumetric (0,5 Bs/m3; then 2 Bs/m3 > 20m3)	Agricultura Crianza de animales menores y ganado menor Reventa y/o rescate de productos agropecuarios Costura Huerto Empleado comercial Misionero	Angostura Lagun Mayu Machu Mita Pozo surgente Conexión dom
10	Zenteno	Villa Esperanza - Canarancho	5	Volumetric (1,20 Bs/m3)	Agricultura Crianza de ganado mayor Crianza de animales menores y ganado menor Venta de chicha Huerto	Lagun Mayu Machu Mita Angostura Riadas Pozo excavado Conexión dom
11	Ureña	Capacachi	6	Volumetric (1,5 Bs/m3)	Negocio independiente Empleado comercial	Conexión dom
12	Medrano	Capacachi	4	Fija (10 Bs/mes)	Agricultura Crianza de ganado mayor Crianza de animales menores y ganado menor Chofer Huerto	Angostura Saytu Kocha
13	Soliz	Capacachi	6	Volumetric (1,6 Bs/m3)	Crianza de ganado mayor Producción y/o venta de quesillo Agricultura Reventa y/o rescate de productos agropecuarios Crianza de animales menores y ganado menor Huerto	Saytu Kocha Angostura Machu Mitha
14	Alarcón	Montecillo	6	Fixed (4 Bs/mes)	Albañil Agricultura Huerto	Conexión dom. Acequias Lagun Mayu Chankas Machu Mita Estanque Riadas
15	Angulo	Montecillo	11	Fixed (4 Bs/mes)	Agricultura Tomero Venta y/o rescate de flores Albañil Chofer	Conexión dom. Chankas Machu Mitha Lagum Mayu Estanque

16	Coria	Montecillo	8	Fixed (4 Bs/mes)	Agricultura Obrero Huerto	Conexión dom. Vertiente Acequias Lluvia Aguas residuales Lagum Mayu Machu Mita Chankas Estanque Riadas
17	Loza	Montecillo	7	Fixed (4 Bs/mes)	Albañil Agricultura Crianza de animales menores y ganado menor Huerto	Conexión dom. Acequias Lluvia Lagun Mayu Saytu Khocha Chankás Estanque Riadas

Table 3 - Total consumption of domestic water (lpcd)

Code	Family	Basic use (lpcd)	Productive uses (lpcd)	Other uses (lpcd)	Total (lpcd)
1	Residencia	147.2	0.0	198.0	345.2
2	Rocha	45.0	5.0	0.0	50.0
3	Rodríguez	53.1	8.5	0.0	61.5
4	Zurita	46.6	10.1	0.0	56.7
5	Aguilar	80.0	106.7	0.0	186.7
6	Amurrio	86.3	126.7	0.0	213.0
7	Claros	44.0	27.4	5.8	77.2
8	Ledezma	90.8	73.8	0.0	164.6
9	López	72.8	16.1	0.0	88.9
10	Zenteno	80.0	66.7	0.0	146.7
11	Ureña	37.2	62.8	0.0	100.0
12	Medrano	100.0	0.0	25.0	125.0
13	Soliz	97.2	180.6	0.0	277.8
14	Alarcón	56.4	0.0	0.0	56.4
15	Angulo	53.4	50.7	0.0	104.1
16	Coria	77.1	79.1	0.0	156.2
17	Loza	64.5	97.6	0.0	162.1
Avg		72.4	53.6	13.5	139.5

Table 4 - Basic use of domestic water supply

Code	Family	Personal sanitation (lpcd)	Drinking (lpcd)	Cooking (lpcd)	Washing utensils (lpcd)	Washing clothes (lpcd)	Cleaning house (lpcd)	Washing car (lpcd)	Basic use (lpcd)
1	Residencia*								147.2
2	Rocha	30.4	0.5	2.8	2.1	3.3	5.8	0.0	45.0
3	Rodríguez	38.5	1.2	1.9	2.3	7.2	2.1	0.0	53.1
4	Zurita	25.2	3.0	0.0	3.0	8.3	0.4	6.7	46.6
5	Aguilar	46.7	1.2	2.3	2.3	21.3	4.8	1.3	80.0
6	Amurrio	54.0	0.6	1.0	2.3	20.0	8.4	0	86.3
7	Claros*								44
8	Ledezma	58.2	1.5	2.1	1.9	25.2	1.8	0.0	90.8
9	López	51.1	1.2	1.8	1.6	9.3	7.8	0.0	72.8
10	Zenteno	53.3	1.7	2.3	1.7	14.7	6.3	0.0	80.0
11	Ureña	27.2	0.8	1.7	2.5	4.4	0.6	0.0	37.2
12	Medrano	47.5	2.5	5.0	17.5	20.0	5.5	2.0	100.0
13	Soliz	81.9	1.5	2.2	0.8	10	0.8	0.0	97.2
14	Alarcón	30.0	0.6	7.2	6.7	8.9	3.1	0.0	56.4
15	Angulo*								53.4
16	Coria	41.7	1.3	2.5	4.6	20.8	6.3	0.0	77.1
17	Loza	35.7	1.2	2.4	7.6	15.2	2.4	0.0	64.5
Avg.	Chillimarca Villa	31.3	1.6	1.6	2.5	6.3	2.8	2.2	73.0
Avg.	Esperanza - Canarancho	52.7	1.3	1.9	1.9	18.1	5.8	0.3	75.7
Avg.	Capacachi	52.2	1.6	3.0	6.9	11.5	2.3	0.7	78.1
Avg.	Montecillo	35.8	1.0	4.0	6.3	15.0	3.9	0.0	62.8
Avg.		44.4	1.3	2.5	4.1	13.5	4.0	0.7	72.4

Note: *breakdown between uses not available

Table 5 - Productive use of domestic water supply

Code	Family	Consumption of domestic water for productive uses (lpcd)				
		Huerta (garden)	Field	Animals	Other	Total
1	Residencia	0.0	0.0	0.0	0.0	0.0
2	Rocha	0.0	0.0	5.0	0.0	5.0
3	Rodríguez	0.0	0.0	8.5	0.0	8.5
4	Zurita	10.0	0.0	0.0	0.1	10.1
5	Aguilar	40.0	0.0	66.7	0.0	106.7
6	Amurrio	80.0	0.0	46.7	0.0	126.7
7	Claros	12.0	0.0	12.0	3.4	27.4
8	Ledezma	38.1	0.0	35.7	0.0	73.8
9	López	11.1	0.0	5.0	0.0	16.1
10	Zenteno	20.0	0.0	46.7	0.0	66.7
11	Ureña	4.4	0.0	58.3	0.0	62.8
12	Medrano	0.0	0.0	0.0	0.0	0.0
13	Soliz	0.0	0.0	180.6	0.0	180.6
14	Alarcón	0.0	0.0	0.0	0.0	0.0
15	Angulo	0.0	27.7	0.0	23.0	50.7
16	Coria	52.1	27.0	0.0	0.0	79.1
17	Loza	47.6	0.0	50.0	0.0	97.6
Avg		18.6	3.2	30.3	1.6	53.6

Table 6 - Irrigation water use from different sources

Code	**Family**	**Annual area cultivated (m^2)**	**Field-scale irrigation from different sources (m^3)**						**Total field-scale irrigation use**		
			Reser-voirs	***Mitas***	***Riadas***	**Wells**	**Springs**	**Dom. supply**	**m3/ year**	**mm/ year**	**lpcd**
1	Residencia	0	0	0	0	0	0	0	0	0	0
2	Rocha	50	18	31	13	0	0	0	63	1254	43
3	Rodríguez	3000	540	2133	648	0	0	0	3321	1107	700
4	Zurita	0	0	0	0	0	0	0	0	0	0
5	Aguilar	20000	12735	5913	3348	0	0	0	21996	1100	12053
6	Amurrio	18200	4050	5754	0	1899	720	0	12423	683	11345
7	Claros	3244	0	0	0	2085	0	0	2085	643	1428
8	Ledesma	27200	5832	6984	0	0	0	0	12816	471	5016
9	López	8300	2472	903	720	0	2916	0	7012	845	3202
10	Zenteno	18900	6596	5910	0	0	0	0	12506	662	6853
11	Medrano	0	0	0	0	0	0	0	0	0	0
12	Ureña	7600	5063	0	1440	0	0	0	6503	856	4454
13	Soliz	55000	35640	0	0	0	0	0	35640	648	16274
14	Alarcón	2600	801	1080	468	0	675	0	3024	1163	1381
15	Angulo	14472	6609	5484	0	0	9148	110	21350	1468	5318
16	Coria	4450	1164	0	288	0	1634	120	3206	720	1098
17	Loza	4166	3313	0	238	0	2380	0	5930	1423	2321
Avg.		*11011*	*4990*	*2011*	*421*	*234*	*1028*	*13*	*8699*	*767*	*4205*