Groundwater use in the high valley of Cochabamba, Bolivia

An inventory on water quantity, water quality and users perspective

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Water Resources Management group

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Bachelor thesis Water Resources Management submitted in partial fulfillment of the degree of Bachelor of Science in International Land and Water Management at Wageningen University, the Netherlands

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PREFACE

Before I start introducing this thesis I want to express my gratitude to all individuals and organizations that made this research possible. Living and working in Bolivia has been an amazing experience and of great value for my professional and personal learning process.

First of all I would like to thank Jeroen Vos from Wageningen University for setting up the communication with the host organization in Bolivia (Centro Agua), for providing advice during the time in Bolivia, for providing feedback on the data analysis, improving my writing skills and last but not least: for learning me to look at things from a critical and more academic perspective.

I would like thank Alfredo Duran from Centro Agua of the Universidad Mayor de San Simon (UMSS) in Cochabamba for the warm welcome at Centro Agua and the organization and help concerning the field work. It was a learning and fun experience to join him in excursions and field work and discuss Bolivia's water issues along the way. I also want to thank Anibal Mayta from Centro Agua, Christian Pereyra and Marcelo Felipe of UMSS for helping me in practical ways and helping me overcome language barriers. In this case as well, it was both a learning and fun experience to live in the field and do research together.

Arthur Heijstek
July 2014

ABSTRACT

In the area of Cliza, Cochabamba in Bolivia groundwater use trough wells is essential for crop production. However there is a concern that groundwater extractions at their current rate are not sustainable and therefore there is a need of information on demand and supply of water as a basis for sustainable groundwater management. This thesis presents a first inventory of groundwater use in Cliza concerning water quantity, water quality and users perspective. The water quantity is measured and the annual quantity discharging from different wells is calculated. Irrigation water quality is measured on pH, electrical conductivity (EC) and temperature. Drinking water quality is measured on pH, EC, turbidity and temperature. Besides this, interviews with users have been done concerning the very beginning and process of obtaining a well until their future perspective concerning groundwater use. The main findings concerning water quantity are that the average discharge per well is 8.1 l/s and the average annual discharge per well is around 140,000 m^3. In terms of water quality, both irrigation water and drinking water score acceptable values on pH, EC and turbidity, however the temperature climate can enable high occurrence of coliform bacteria. Water users obtain their well with support from the local municipality and organize themselves through a Water Users Organization (WUO). In general, users have a positive perception on the quality of both drinking water and irrigation water. The perception on the quantity of drinking water is positive in general as well, however this is not the case concerning the quantity irrigation water. At last, a main finding is that the majority of the interviewed users want to have more water available in the future.

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1. INTRODUCTION

Globally, intensive groundwater use in agriculture has become a dominant, yet under perceived aspect of contemporary water use. Global groundwater use has grown exponentially in scale and intensity over recent decades. In all parts of the developing world a key common priority is to improve the understanding of groundwater supply and demand conditions, and create effective programs for public education in the sustainable use of groundwater resources (Shah, et al., 2007).

El Valle Alto (high valley) of Cochabamba is an important agricultural district in Bolivia. The climate is semi-arid with rainfall occurring mostly between November and March. This means that the region is dependent on irrigation for their agriculture and economy throughout the year. Therefore groundwater extraction is a growing source for irrigation, even more since there are excellent alluvial aquifers in the region. Recent groundwater studies by the Universidad Mayor de San Simon (UMSS) of Cochabamba and Universidad San Francisco Xavier (USFX) of Sucre found evidence of a descending groundwater level of 2.2 meters between November 2011 and November 2012 in the nearby located Punata (Ortiz, 2013). Therefore there is a concern by the Municipality of Cliza (MOC) and the water user organization's (WUO's) that groundwater extractions are not sustainable at their current rate in Cliza. As a response to this concern the MOC, Federation of Canadian Municipalities (FDM, Cliza is a sister town of Truro, Canada) and Centro Agua of the UMSS recently began a partnership to establish a groundwater level monitoring network. A study will we conducted on demand of water (inventory), supply of water (study of the aquifer) and based on this data a water balance can be made and used to support a groundwater management plan for the municipality of Cliza (UMSS and USFX, 2013).

Since there is a concern that groundwater extractions at their current rate are not sustainable there is need of information on demand and supply of water as a basis for sustainable groundwater management. This research aims at investigating the current state of groundwater use in Cliza, Cochabamba to generate knowledge on the current groundwater demand and also the users perspective concerning this. An inventory of groundwater use will be done concerning water quantity, water quality and users perspective, see figure 1.

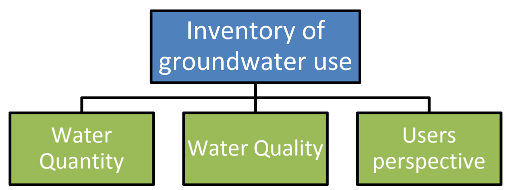

Figure 1 Overview of research

Main Research Question (MRQ):

- What is the current state of groundwater use in terms of water quantity, water quality and users perspective in Cliza?

Secondary Research Questions (SRQ):

- **SRQ1:** what is the quantity of groundwater discharging from the wells?
- **SRQ2:** what is the physical quality of the groundwater discharging from the wells?
- **SRQ3:** what is the users perspective concerning the groundwater use?

This report will start with background information from the national scale of Bolivia till the local level of Cliza (chapter 2). Then in the next chapter the methodology of data collection, used concepts and literature for data analysis will be explained (chapter 3). In the next chapter results of the data collection and their analysis according to literature are presented (chapter 4: results) followed by a conclusion where the research questions will be answered (chapter 5). The last chapter will discuss the reliability of the results, its interpretation, the relationship between Cliza and the global discussion of sustainable groundwater management and is closed with a section on the usefulness of the result and future recommendations (chapter 6).

2. BACKGROUND

Background information is useful in order to get an idea of the context concerning the research area. Therefore this chapter will start with background information from a national scale of Bolivia till the local level of Cliza.

2.1 BOLIVIA

Bolivia is a landlocked country in the heart of the South America and shares its borders with Argentina, Brazil, Chile, Paraguay and Peru. In 2004 its population has been estimated on nearly 9.3 million, with an annual growth rate of 2.4 percent and 45 percent of the population lives in rural areas (Vera, 2006). The country has a land area of 1,098,580 square kilometers and a population density of 8.5 people per square kilometer. Ethnically, Bolivia is not dominated by any single group of people, but according to a survey in 2001, 30 percent is mixed race, 28 percent Quechua, 19 percent Aymara, 12 percent European and the remaining 11 percent come from a collection of ethnicities. Spanish is spoken by 87 percent of the population and Quechua and Aymara are the other common languages. Despite efforts at reforming the country, Bolivia's economic development has been continually hindered by political unrest, a lack of economic diversification and the extremely profitable, but internationally condemned, illegal drug trade (Library of Congress, 2006). However, the percentage of Bolivians living in extreme poverty decreased from 41.2% in 1996 till 32,7% in 2008 (UNDP, 2010). According to the Ministry of Agriculture 15 percent of the land is arable and suitable for agriculture of which 12 percent was in use in 2006 (Library of Congress, 2006). Agriculture is an important sector in Bolivia and accounted for 23 percent of GDP in 1987 and employed about half of official labor force in 1986. The Andes mountain range defines the country's three geographic zones: the mountains and Altiplano in the west, the semi-tropical Yungas and temperate valleys of the eastern mountain slopes, and the eastern tropical lowlands. Due to the high variety in geographic zones climate conditions vary widely as well. From tropical conditions in the lowlands to polar conditions in the highest parts of the Andes. In most places rainfall is heaviest in summer, and yearly amounts tend to decrease from north to south. The valleys of the eastern mountain slopes cover 15 percent of the country and have 24 percent and 36 percent of the urban and rural population of the country respectively. The valleys in general have Mediterranean climates, with rainfall concentrated in a few months ranging between 200 and 600 mm. Crops, roots, fruits, vegetables and sows forages are grown and if irrigation is available more than one cropping season is feasible (Vera, 2006). Agricultural production in Bolivia is complicated by both the country's topography and climate. High elevations make farming difficult, as do the El Niño weather patterns and seasonal flooding. Bolivia's agricultural GDP continues to rise but has attained only a rather modest average growth rate of 2.8 percent annually since 1991 (Library of Congress, 2006).

2.2 RESEARCH AREA: CLIZA, COCHABAMBA

The study area of this research is located in the municipality of Cliza, which in Centrally located in the department of Cochabamba. The municipality is located 17 º 35 '05'' south latitude and 65 º 57' 15'' west longitude (see figure 2) and covers the central part of the Valley of Cochabamba (Municipio de Cliza, 2010). The Valley of Cochabamba is located in the valleys of the eastern mountain slopes of Bolivia. The climate is arid to semi-arid, has moderate rainfalls and high evapotranspiration and therefore is known to suffer from water shortages. In the midst of this, rapid population growth in the Valley of Cochabamba has created an even greater demand for water, mainly needed for irrigation and human consumption. Groundwater therefore has been exploited in the region through the use of excavated wells since colonial times and through the Republican period and since the beginning of this century mechanical perforations of small diameter are drilled.

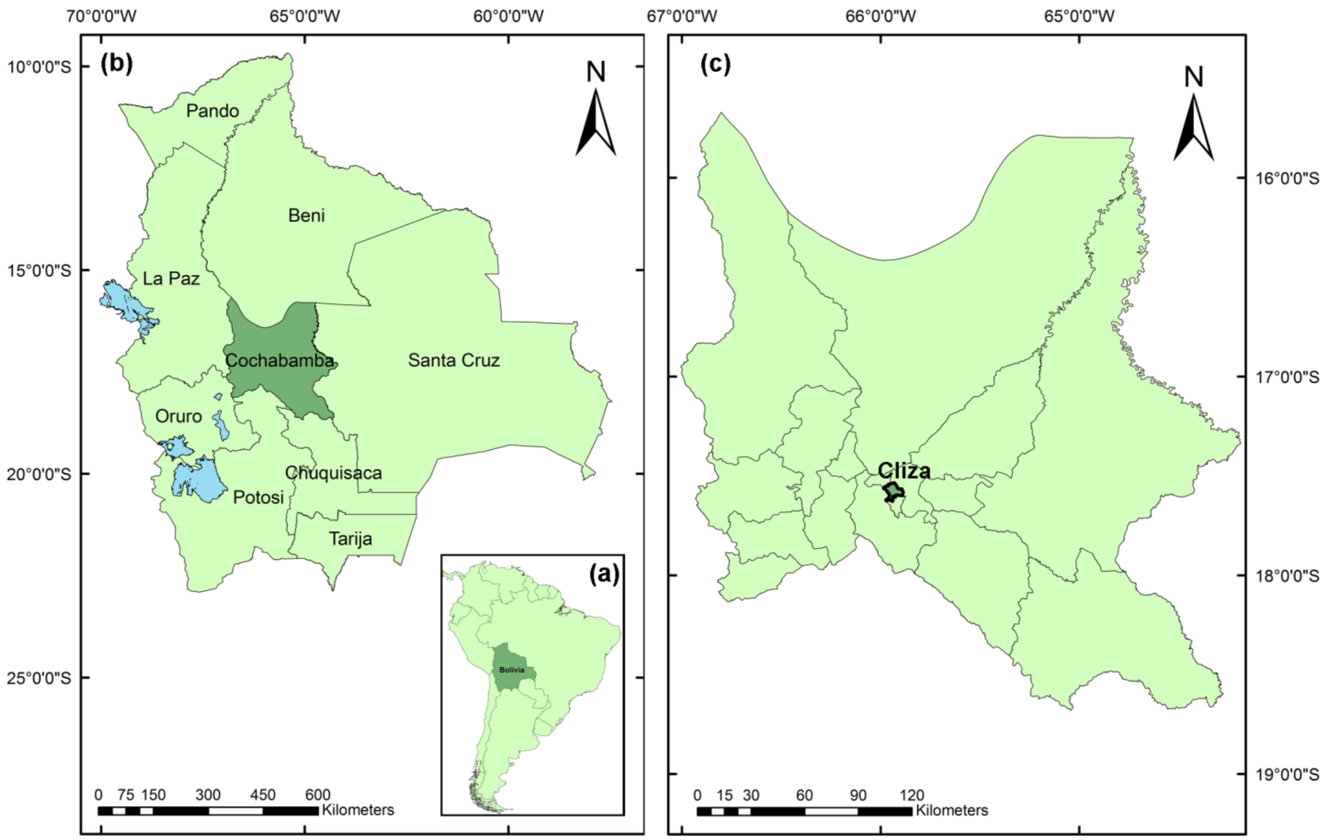

Figure 2 Bolivia located in South America (a), Department of Cochabamba located in Bolivia (b), Municipality of Cliza located in the department of Cochabamba, created from available GIS data from Ministerio de Desarrollo Sostenible, (2004)

Cliza itself is characterized by a valley surrounded by mountains and has an area of 68,15 square kilometers. Of this area, 52 square kilometers (76% of total) is used for intensive agricultural use, meaning annual and perennial crops are crown as and cattle is used for work and for the production of beef and dairy products. The remaining area consist of 9 square kilometers with a limited use (shallow soils, salinity, water bodies) and 7 square kilometers of urban area. Cliza has an altitude between 2,700 and 3,000 m, an average temperature of 16 degrees and an arid climate with annual rainfall between 400 and 450 mm, occurring mostly between September and April, see

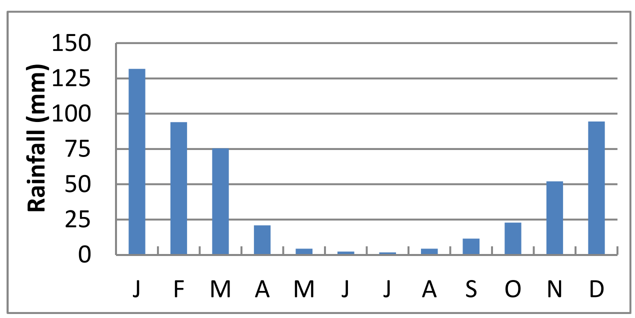

Figure 3 Average monthly rainfall in mm over a period of 52 years, source: (Municipio de Cliza, 2010)

figure 3 (Municipio de Cliza, 2010). Cliza is located in the ‘Cliza-Sulty’ watershed which has a drainage area of 1966 km^2 and the main river flowing through the municipality is called the ‘Rio Cliza’. According to FAO (2000) the area of Cliza contains of two soil types: chromic luvisols with more than 35% clay and lithosols.

The area used in Cliza for agriculture counts 3360 hectares and is used to grow maize (70%), potatoes (15%) and alfalfa (12%) and a small percentage is used to grow vegetables. These crops are partially used for own consumption and partially for merchandising, see table 1. (Municipio de Cliza, 2004). Limitations in the availability of surface water in combination with the climate conditions have generated a particular form of production where crops are irrigated with groundwater from wells. The area had a total of 145 wells in 2010, of which 51 are communal irrigation wells, 67 private irrigation wells and 27 drinking water wells (Municipio de Cliza, 2010). In 2001 Cliza counted a total 19,992 inhabitants of which 56% lives in rural areas (Municipio de Cliza, 2004). It was estimated in 2001 that about 25% works in in agricultural activities, 18% in trade, 13% in the manufacturing, 10% in construction and the remaining percentage in jobs that are generated by education and transport. Besides this, only 44% of the working age population is economically active and it is estimated that poverty has an impact on 47% of Cliza’s population (Municipio de Cliza, 2010).

Table 1 Crops grown in Cliza and their proportion of consumption and merchandise, adapted from (Municipio de Cliza, 2004)

Crop	% of total	% for consumption	% for merchandising
Maize	70.03	42%	58%
Potatoes	15	85%	15%
Beans	1.19	24%	76%
Peas	0.39	40%	60%
Wheat	0.3	50%	50%
Alfalfa	11.9	50%	50%
Peach	1.19	20%	80%

3. METHODOLOGY

The research area is determined by the project of Centro Agua, UMSS, USFX, MOC and FDM. Within the research area the sampling sites were selected randomly with the criteria to get as much spatial variety within the available time for data collection (4 weeks). The spatial variety is desired since this study is a first general inventory in the research area. Randomly in this case means visiting community for community and based upon a community's availability a site was selected for sampling, wells were located with the help of the community and by following the overland electrical wires to the fields. The methods of data collection and literature that have been used for data analysis are explained in this section.

3.1 WATER QUANTITY

The water quantity parameter that has been measured to answer SRQ1 is the discharge leaving the well. The quantity leaving a well has been expressed and measured in discharge (Q), meaning the amount of liters that leave the well per second. Q is measured by letting either a bucket of 30 or 45 liters fill up and calculated by dividing this volume by the time it took to fill up the bucket. For wells that appeared to have a high discharge the bucket of 45 liters was preferred over the bucket of 30 liters in order to get a higher accuracy. Per well a measurement has been repeated 3 till 5 times, and the average value was calculated and used for data analysis.

In order to get an indication of the annual quantity discharging from the wells, the measured discharge has to be combined with the annual time of functioning of a well. Therefore questionnaires will be done concerning the daily functioning in hours and the functioning of days per month. Based on these data the annual quantity of water in m^3 will be calculated as the following:

$$\frac{\mathrm{Q}\left(\frac{\mathrm{l}}{\mathrm{s}}\right) * 3600\ s * daily\ functioning\ (hr) * montly\ functioning\ (d) * yearly\ functioning\ (months)}{1000\ \mathrm{l}}$$

3.2 WATER QUALITY PARAMETERS AND STANDARDS

The water quality parameters that have been measured to answer SRQ2 are pH, electrical conductivity (EC), turbidity and temperature, these parameters have been selected based on available equipment. In this study the used meaning for water quality is described by the World Health Organization (WHO): Water quality is a term used to express the suitability of water to sustain various uses or processes. Any particular use will have certain requirements for the physical, chemical or biological characteristics of water (WHO, 1996). Drinking water and irrigation water have been analyzed trough different literature since both have different uses and therefore also different requirements. The water quality parameters, literature for analysis, data collection methods and used instruments are explained in the following sections.

3.2.1 PH

The pH of a solution is the negative common logarithm of the hydrogen ion activity, in other words: pH = -log (H^+). The pH is of major importance in determining the corrosivity of water. In general, the lower the pH, the higher the level of corrosion. For effective disinfection with chlorine, the pH should preferably be less than 8. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Failure to do so can result in the contamination of drinking-water and in adverse effects on its taste, odour, and appearance (WHO, 2008).

According to the WHO the optimum pH for drinking water will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but is often in the range of 6.5–9.5 (WHO, 2012).

According to Yiasoumi, et al. (2005) the generally accepted pH for irrigation water is between 5.5 and 8.5, but some problems can occur within this range. For example, alkaline water may contain high concentrations of bicarbonate (generally in water of pH 8 and above) and carbonates (generally pH 9 and above). High bicarbonate and carbonate levels in water can cause calcium to precipitate from the soil: this reduces the soil's exchangeable calcium content and increases soil sodicity (Yiasoumi, et al., 2005)

pH measurements have been done with a Wagtech Pocket pH Meter, 1 measurement per sample has been done and the instrument has been calibrated every 6-8 measurements with a buffer solution of a pH of 7.

3.2.2 ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) represents the ability of water to conduct an electric current and is an indicator of the salinity or mineral content of water (Rhoades, et al., 1992). Conductivity can be expressed in different ways but in this study is expressed in micro Siemens per cm (uS/cm), since the measure instrument that was used uses this unit. High salinity can result in nutrient toxicity and reduced water uptake by the plants (Amundson, et al., 2012). An approximate relation (because it also depends upon specific ionic composition) between EC and total salt concentration is 1000 uS/cm = 700 mg/l. Electrical conductivity values are always expressed at a standard temperature of 25 °C to enable comparison of readings taken under varying climatic conditions (Rhoades, et al., 1992).

The classification of water salinity based on EC that will be used in this report, is displayed in table 2.

Table 2 Water classes in terms of salinity based on EC, adapted from (Rhoades, et al., 1992)

Water class	Electrical conductivity uS/cm	Salt concentration mg/l	Type of water
Non-saline	<700	<500	Drinking and irrigation water
Slightly saline	700 – 2,000	500-1500	Irrigation water
Moderately saline	2,000 – 10,000	1500-7000	Primary drainage water and groundwater
Highly saline	10,000-25,000	7000-15 000	Secondary drainage water and groundwater
Very highly saline	25,000 – 45,000	1 5 000-35 000	Very saline groundwater
Brine	>45,000	>45 000	Seawater

EC has been measured with a Wagtech Pocket Conductivity Meter, 1 measurement per sample has been done and the instrument has been calibrated every 6-8 measurement with a solution of 1413 uS/cm.

3.2.3 TURBIDITY

Turbidity is the amount of cloudiness in the water. This can vary from a river full of mud and silt where it would be impossible to see through the water (high turbidity), to a spring water which appears to be completely clear (low turbidity). Turbidity can be caused by: silt, sand and mud (1); bacteria and other germs (2) and chemical precipitates (3) (WHO, 2008).

Drinking water quality standards are defined by WHO (2008) as the following:

- Drinking water should have a turbidity of 5 NTU or less, turbidity of more than 5 NTU would be noticed by users and may cause rejection of the supply.
- Where water is chlorinated, turbidity should be less than 5 NTU and preferably less than 1 NTU for chlorination to be effective (2).

Turbidity will only be investigated for drinking water wells, since this parameter is essential for drinking water quality, while in the case of irrigation water no official standards or literature were found stating the significance of turbidity for irrigation water.

Turbidity has been measured with a Wagtech 3-part turbidity tube, 1 measurement has been done per sample and this instrument did not need to be calibrated. This instrument can measure turbidity as small as 5 NTU and therefore this study will not investigate whether chlorination will be effective or not.

3.2.4 TEMPERATURE

Cool water is generally more tasteful than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of microorganisms and may increase taste, odour, color and corrosion problems (WHO, 2008).

LeChevallier (2003) found out that, on average, the occurrence of coliform bacteria was significantly higher when water temperatures were above 15 °C. Occurrence of coliform bacteria can result in contamination of irrigated crops (Steele and Odumeru, 2004). Temperature is widely recognized as an important controlling factor in influencing bacterial growth. In climates where water temperatures are warm, bacterial growth may be very rapid (LeChevallier, 2003). Temperature has been measured with a Wagtech Pocket pH Meter and one measurement has been done per sample.

3.3 USERS PERSPECTIVE

To answer SRQ3 a semi-structured questionnaire has been set up together with the host organization (Centro Agua) concerning the very beginning of the process of obtaining a well until the future perspective of users concerning their groundwater use. All topics that were part of the questionnaire are displayed here below (see annex 1 for the complete questionnaire):

- Process of obtaining a well and locating a well
- Organization and water distribution
- Agricultural production
- Maintenance
- Problems with functioning of a well and/or water distribution network
- Perceptions on water quantity and quality
- Future perspective

3.4 GROUND WATER USE AND SUSTAINABLE MANAGEMENT

In order to place the case of Cliza its groundwater use in a wider academic perspective, the case will be compared with the global discussion concerning groundwater use and it´s sustainability that is summarized in Shah et al. (2007). A summary of this article is given here below, sustainability of groundwater is defined and the water balance approach is presented.

The use of groundwater in agriculture has become a dominant, yet under perceived aspect of contemporary water use. The groundwater boom has been driven by supply-push factors, such as government subsidies and easy availability of inexpensive pumps and drilling technologies. Demand-pull factors have also contributed, arising from groundwater's capacity to provide flexible, on-demand irrigation to support vibrant, wealth-creating agriculture in all climate zones and from the growing need to provide food for urban populations (Shah, et al., 2007). Sustainability of groundwater use in this case is defined by Wright et al. (2000) as: 'use that does not cause long-term deterioration of the overall resource, in terms of any measurable criteria (e.g. quality and quantity)'. A debate has emerged among hydro geologists over the widely used notion of sustainable yield of aquifers. To manage groundwater resources properly and to identify effective resource management an improved understanding of aquifer behavior has to be combined with an appreciation of the socioeconomic drivers of intensive groundwater use (Shah, et al., 2007).

Wright et al. (2000) provide a water balance approach in order to come to sustainable groundwater management. They state the average effective aquifer recharge should be bigger or equal than the sum of: local basis human needs (1), local ecological needs (2), groundwater outflow necessary for the support of basic human needs and aquatic ecosystems elsewhere (3) and groundwater allocated for local inessential uses (4). In other words the groundwater supply of the aquifer should cover these 4 demands.

4. RESULTS

The geographical location of 64 wells which were located and used for data collection are displayed in figure 4, for a list with UTM coordinates and data per well see annex 2. Based on questionnaires it can be stated that of these 64 wells, 39 are used for irrigation, 11 for drinking water, 1 for mixed use (drinking water and irrigation) and of the remaining 13 wells the use is unknown. The type of wells that are used are drilled wells, which are constructed by either percussion or rotary-drilling machines and can be drilled deeper than 300 meters (Waller, 1994). In the case of Cliza wells currently are drilled until a depth of around 100 meters, have diameter ranging from 2 till 8 inch and are electrically powered.

This chapter consists of the results of the water quantity and water quality measurements and their analysis according to literature followed by the results of questionnaires on the users perspective.

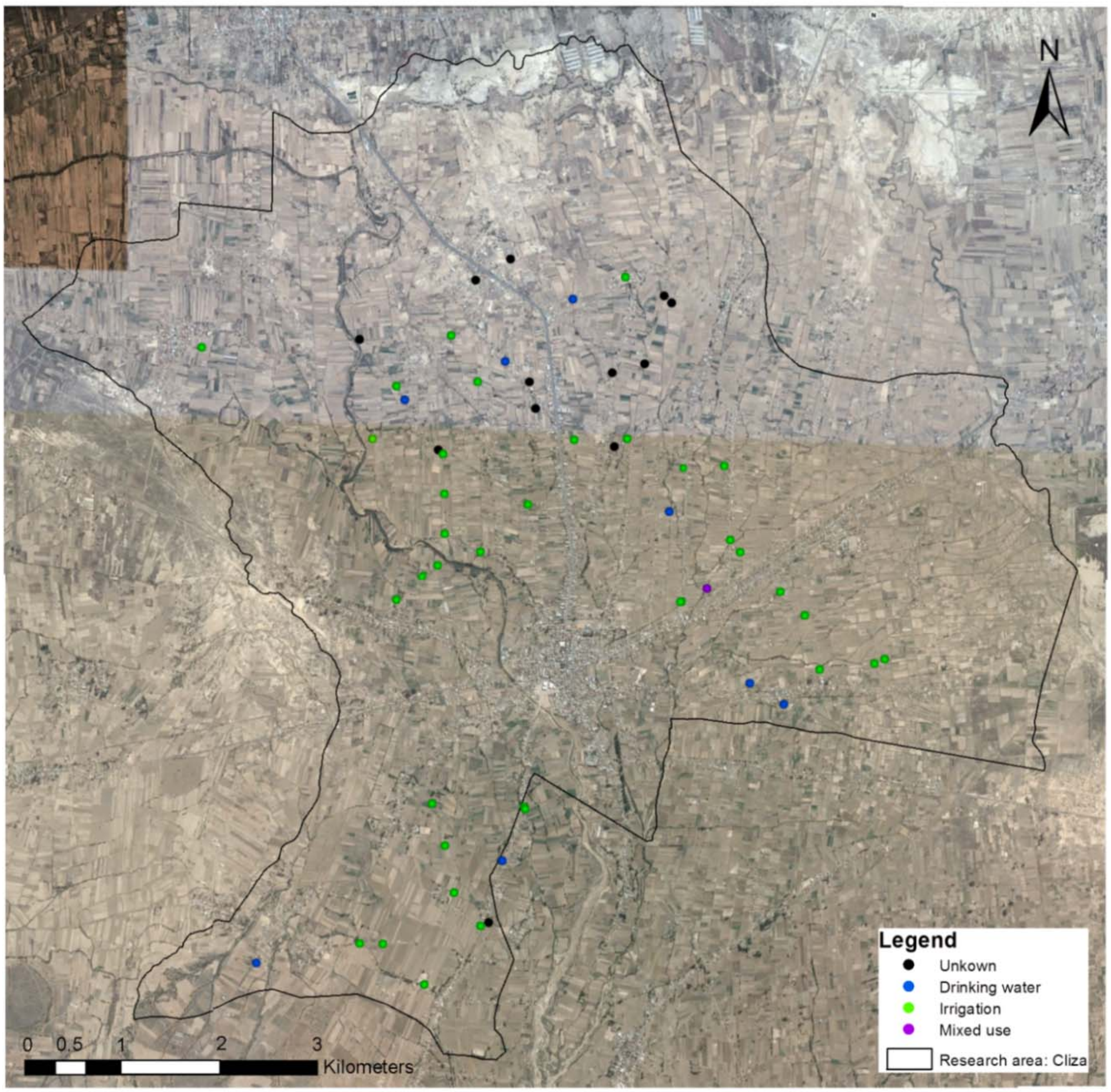

Figure 4 Geographical location of 64 wells within the research area, source: own elaboration displayed on Google Earth maps, image taken on 26-07-2013, accessed on 18-06-2014.

4.1 WATER QUANTITY: DISCHARGE (Q)

The range of discharge of the 34 wells that are measured is between 1.5 and 22.5 l/s and the average discharge is 8.1 l/s. In table 3 the distribution of wells is categorized by groups of discharge shows and shows that the majority (24 out of 34) of discharges range between 1.5 and 10 l/s. The deviations in discharge values can be explained by the fact that if a certain discharge is required, pumped from a certain depth, a certain pumping force is required. In figure 5 it becomes clear that there is relationship (R^2 = 0.76 and 0.99) between Q and pumping force pumped from two different classes of depths.

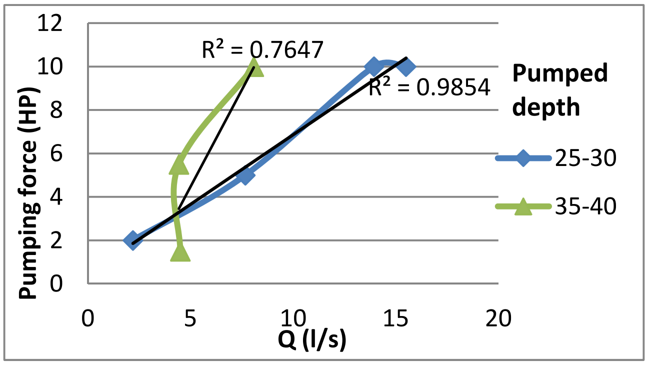

Figure 5 Relationship Q and pumping force from a certain depth

Table 3 Range of discharge (Q) values

Q (l/s)	1.5-5	5-10	10-15	15-20	20-22.5	total
No. wells	14	10	5	3	2	34

Combining the measured discharge of a well and it's time of function per year give an indication of the annual quantity discharging from a well and therefore the values have been rounded up to values with an interval of 1000 m^3. The annual quantity discharging from the wells is between 60,000 and 400,000 m^3 and the average is 140,000 m^3, see table 4.

Table 4 Annual quantities discharging from the wells

Q (m3/year)	60,000-100,000	100,000-150,000	150,000-200,000	200,000-250,000	400,000	Total
No. wells	7	3	4	1	1	16

4.2 WATER QUALITY OF IRRIGATION WATER

4.2.1 PH

Table 5 Range of pH values for irrigation water

pH		6.5-7	7-7.5	7.5-8	8-8.6	Total
No. wells		7	7	7	3	24

The range of the 24 wells that are measured is between a pH of 6.5 and 8.8 and the average pH is 7.3. In table 5 it can be seen that the pH values are equally divided in 3 categories between 6.5 and 8 with an interval of 0.5 and only 12.5% (3 out of 24) exceeds an pH value of 8. As stated earlier in chapter 3.2.1, generally accepted values for irrigation water are between 5.5 and 8.5. In this case all values are within this range, except for one (pH=8.6).

4.2.2 ELECTRICAL CONDUCTIVITY (EC)

The range of the 28 wells that are measured on electrical conductivity is between 290 and 1660 uS/cm and the average value is 626 uS/cm, see table 6 for the range of values categorized below and above 700 uS/cm. Comparing these data to the classes of salinity of the water, mentioned in chapter 3.3.2, it could be stated that 75% of the groundwater samples is non-saline, 25% slightly saline and that none of the samples are classified as moderate or highly saline. According to Rhoades, et al. (1992) slightly saline water can still be considered as irrigation water therefore it can be stated that all values can be considered as irrigation water.

Since there is high variety in EC values, the values have been plotted spatially in figure 8 and have been compared with the pumped depth in figure 7 to see if the deviations in values can be explained. However both figures indicate that based on these data there is no clear zoning of EC values spatially (see figure 6) or a clear relationship between EC and pumped depth (see figure 7, R^2=0.08).

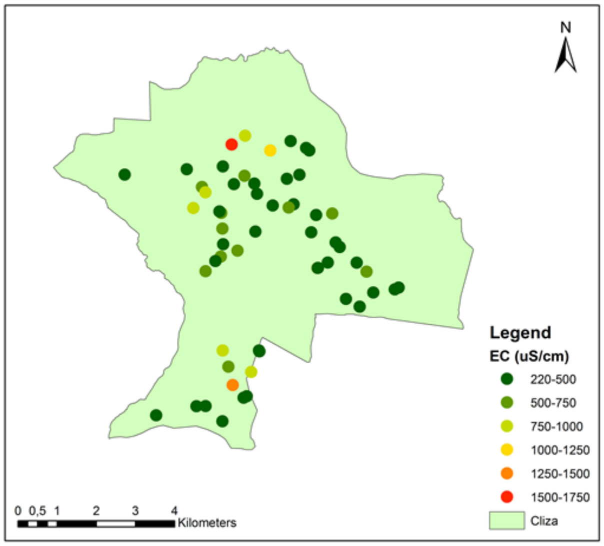

Figure 6 Spatial distribution EC

Table 6 Range of EC values for irrigation water

EC (uS/cm)	<700	700-2000	Total
No. wells	21	7	28

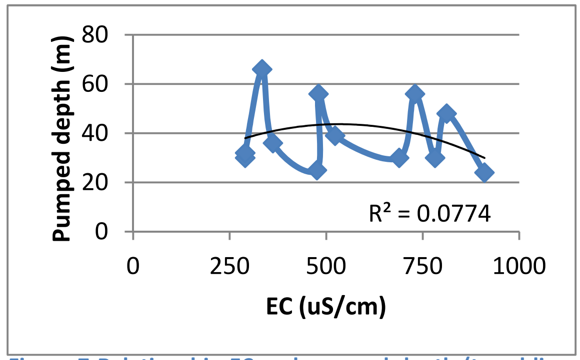

Figure 7 Relationship EC and pumped depth (trend line: polynomial)

4.2.4 TEMPERATURE

The range of 25 wells measured on temperature is between 18.3 and 23.5 °C, and the average temperature is 21 °C. In table 7 it can be seen that the majority of the values ranges between 20 and 22 °C. LeChavallier (2003) indicates that in water with temperatures above 15 °C there is a significant higher occurrence coliform bacteria. in this case all values exceed 15 °C meaning the temperature climate can enable high occurrence of coliform bacteria.

Table 7 Range of temperature values for irrigation water

Temperature(°C)	18-20	20-22	22-24	Total
No. wells	5	14	7	26

4.3 WATER QUALITY OF DRINKING WATER

4.3.1 PH

The range of the 8 wells measured is between a pH of 6.5 and 7.7 and the average pH is 7.2, the distribution of the values categorized in intervals of a pH value of 0.5 are displayed in table 8. As stated by WHO (2012) in chapter 3.2.1 the optimum pH for drinking water is between 6.5 and 9.5, all values in this case fall within this range.

Table 8 Range of pH values for drinking water

pH	6.5-7	7-7.5	7.5-8	Total
No. wells	2	4	2	8

4.3.2 ELECTRICAL CONDUCTIVITY

The range of the 10 wells that are measured on electrical conductivity is between 220 and 1025 uS/cm and the average value is 536 uS/cm. In table 9 it can be seen that 70% of the values is considered non-saline and 30% slightly saline, which is to be classified as irrigation water but not as drinking water.

Table 9 Range of EC values for drinking water, classification according to (Rhoades, et al., 1992)

EC (uS/cm)	<700)	700-2000	Total
Amount of wells	7	3	10

4.3.3 TURBIDITY

All 10 wells that are measured on turbidity have a value lower than 5 NTU, indicating that all values fall within the range of acceptable drinking water based on this parameter according to WHO (2008).

4.3.4 TEMPERATURE

The range of 8 wells that are measured on temperature is between 18.3 and 23.5 °C, and the average temperature is 21 °C. In table 10 it can be seen that the majority of the values ranges between 20 and 22 °C and all values exceed the critical value of 15 °C according to LeChavallier (2003), meaning the temperature climate can enable high occurrence of coliform bacteria.

Table 10 Range of temperature values for drinking water

Temperature (°C)	18-20	20-22	22-24	total
No. wells	3	2	2	7

4.4 USERS PERSPECTIVE

4.4.1 PROCESS OF OBTAINING A WELL AND LOCATING A WELL

When a group of inhabitants wants a well for drinking water or irrigation they organize themselves by having joint meetings where they write a proposal expressing their needs to the municipality. Once this proposal is accepted, the municipality will pay a part itself or trough large scale governments projects and the group of inhabitants pay their counterpart (varying between 15 and 40%). With this money a local company is hired to drill the well. Currently no permits are needed to drill a well nor are there limitations on water use.

For the determination of locating a well first an area is selected by the users according to their land rights or convenience. Then within the borders of this area a geophysical study on the subsurface is executed with an geophysical resistivity device on 2 till 4 points, and the point with the best results is chosen. This technique is based on the response of the earth to the flow of an electrical current and gives lithologic and geohydrologic information on the subsurface (Cardimona, 2002). Besides this, users have own experience or learned from others experience at what depths and locations salty water can be found and this knowledge is included in the decision making process.

4.4.2 ORGANIZATION AND WATER DISTRIBUTION

The distribution of water, maintenance of infrastructure and wells and regular user meetings are all organized through a Water Users Organization (WUO). In general a WUO consist of a president, vice-president, secretary of payments, secretary of acts, 2 informants and a well-operator, the tasks of every position are described in table 11. For the sake of equity board members are changed every one or two years between all users. All users are gathered in meetings where the functioning of the well and user’s needs, concerns etc. are discussed, the interval of these meetings varies between once a month till ‘when users think it is necessary’. If a user wants water, he or she has to go the secretary of payments, pay in advance the amount of water he/she wants and decide on when he/she wants it. Then the secretary of payments instructs the well-operator to operate the well according to this agreement. So users do not have direct access to the well but via the secretary of payments and the well-operator. Costs for drinking water are expressed per cubic meter and costs for irrigation water are expressed per hour of functioning of the well. Finances, gained from these payments, are used for maintenance of the well and water infrastructure.

Table 11 Positions and related tasks within the board of a WUO

Position	Tasks
President	Overall responsible, main representative of all users
Vice-President	Second responsible, second representative of all users
Secretary of payments	Manager of finances, receives money directly from users and orders the operator on when and for whom the well can be in function.
Secretary of acts	Responsible of administration
Informant (2)	Supporting the president and vice-president, inform all users on news, date of next users meetings etc.
Well-operator	Operates the well according to the information of the secretary of payments.

Acquiring water rights and to be part of a WUO requires a new user to pay an entry fee, in cases this fee is low if a user already has a property of land located close to a well and can be higher if a new user needs to buy a property of land. All members of the WUO have equal water rights and pay the same amount for irrigation water which on average is 5 Boliviano's per hour of pump functioning. People outside the WUO can have access to this water as well, when the WUO considers this water to be available, but pay 2 till 4 times as much for water than WUO members, which on average is 16.5 Boliviano's per hour. WUO members are obligated to attend WUO joint meetings and other joint activities, like doing maintenance on the earthen irrigation channels, water tanks and pumps. If WUO members does not comply with obligations decided by the WUO, a fine has to be paid in first instance, with the ultimate risk of losing water rights.

4.4.3 AGRICULTURAL PRODUCTION

The crops that 20 interviewed farmers irrigate with groundwater are displayed in figure 8. All farmers that were interviewed irrigated their crops through flood irrigation. Results show that in general farmers use two different growing seasons for Maize, respectively from September till March and August till February. Potatoes are mainly irrigated from July till mid-November, alfalfa the whole year round used for forage and beans are grown between March and mid-November. A general farmers strategy concerning potato and field beans was discovered, namely: farmers state that potatoes and beans are more sensitive to water logging then Maize and therefore grow these in the dry season so they can control the quantity of water supply exactly by irrigating with groundwater.

Figure 8 Crops irrigated in Cliza, own elaboration displayed on the division of average monthly rainfall, source: Municipio de Cliza (2010)

4.4.4 MAINTENANCE OF A WELL

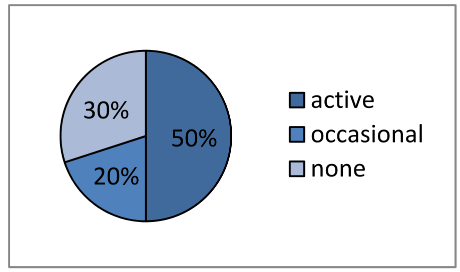

Figure 9 Maintenance of the wells, n=27

Pump controls appear to break often and replacement are done by members of the WUO and by money from the WUO, as well as replacing pipes from the water distribution infrastructure. Maintenance like replacing a pump of a well, or placing the pump deeper (in order to still have water) are often done by a company hired by the WUO. When this maintenance lies within the capability of the WUO, the WUO will perform this maintenance in first instance due to financial motives. Drinking water tanks are cleaned with chorine, to remove any occurrence of algae, every 2 till 6 months. Of the 20 users questioned about maintenance, 50% could report active maintenance and control on the well (preventive), 20% stated they did maintenance when a problem occurs (reactive) and 30% stated no maintenance has been done yet, which can be explained by the fact that in these cases the well started functioning recently (2012-2013), see figure 9. No well was encountered that stopped functioning due to lack of maintenance.

4.4.5 PROBLEMS WITH FUNCTIONING OF A WELL AND/OR WATER DISTRIBUTION NETWORK

In figure 10, primarily it becomes clear that frequent pump and pump control breakage are the main experienced problems. Besides this, canal losses, corrosion in the system and a lack of maintenance are experienced problems. Finally 40% over the 20 interviewees stated to have no experienced problems.

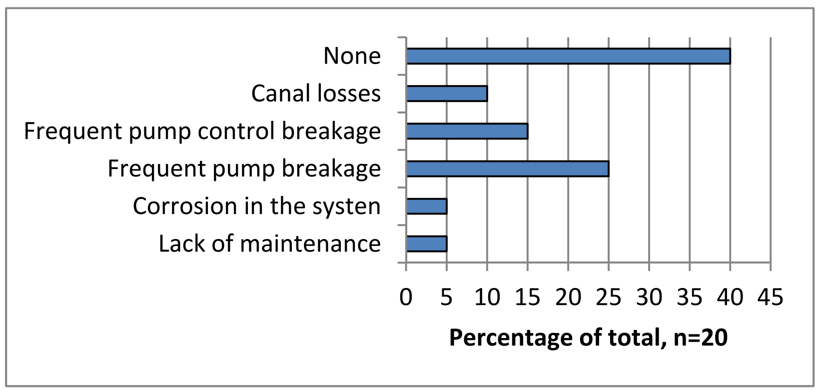

Figure 10 Problems with functioning of a well and/or water distribution network

4.4.6 PERCEPTIONS ON WATER QUANTITY AND QUALITY

From the users that were interviewed on their perception on the quantity of drinking water, 60% stated it is sufficient, 20% stated it is abundant and 20% stated they are lacking water. Besides this, 80% stated their drinking water quality is good and 20% stated is bad. For an overview, see figure 11.

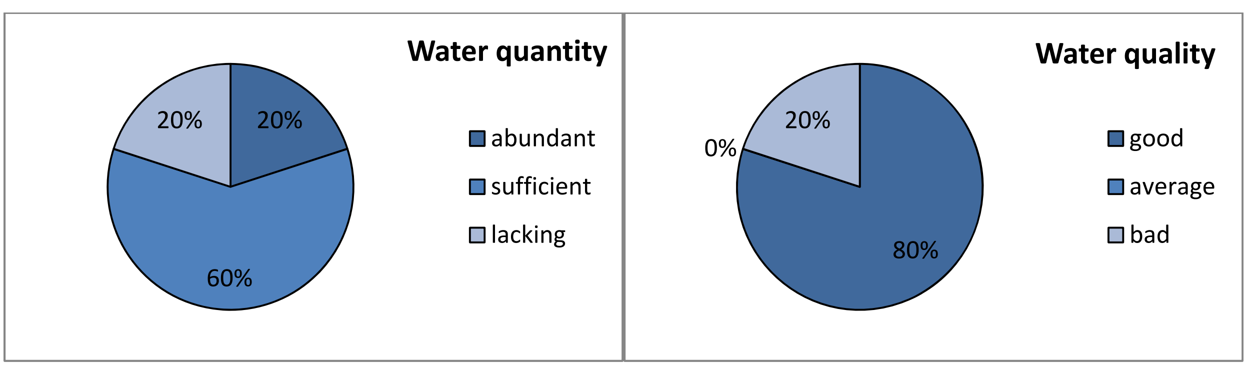

Figure 11 Perceptions on water quantity and quality of drinking water, n=5

From the users that were interviewed on their perception on the quantity of irrigation water, 57% stated they are lacking water, 36% stated it is sufficient and 7% stated it is abundant. Besides this, 73% stated the quality of their irrigation water is good, 20% stated it has average quality and 7% couldn't make a statement. For an overview, see figure 12.

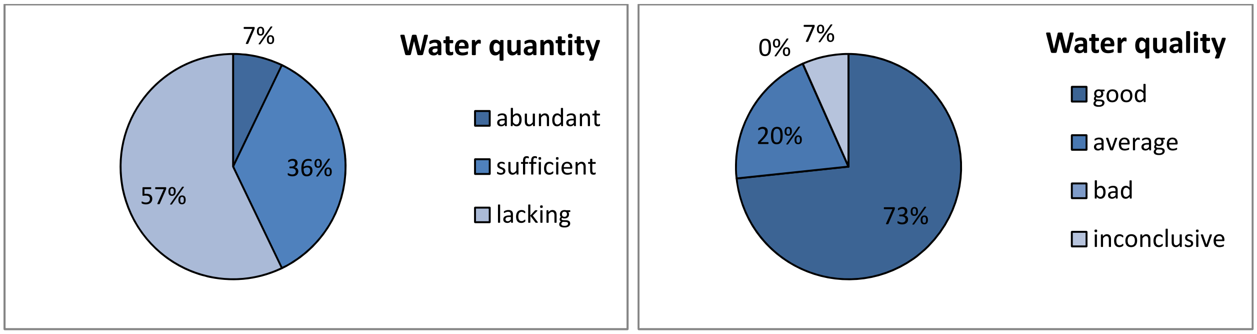

Figure 12 Perceptions on water quantity and quality of irrigation water, n=15

4.4.7 FUTURE PERSPECTIVE

Concerning the users future perspective, figure 13 clearly indicates that the majority wants to have more wells and water available. Only a small part of the interviewees thinks of measures outside the scope of having more water available and focusses on water saving measures like more water distribution through pipes and the use of sprinkler irrigation.

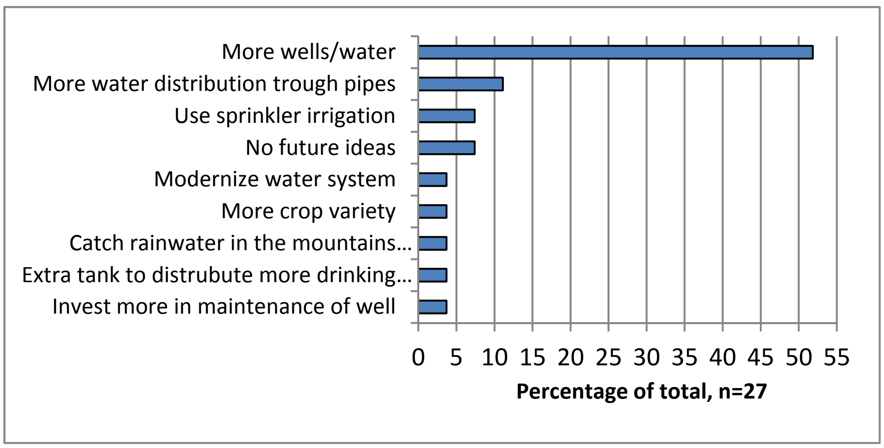

Figure 13 Users future perspective

5. CONCLUSION

Since there is a concern that groundwater extractions at their current rate are not sustainable in Cliza there is need of information on demand and supply of water as a basis for sustainable groundwater management. Therefore this thesis investigated the current state of groundwater use in Cliza as an first inventory. The MRQ that has been set up is: '*What is the current state of groundwater use in terms of water quantity, water quality and users perspective in Cliza, Cochabamba?'* The 3 SRQ's that have been set up to answer the MRQ are: '*what is the quantity of groundwater discharging from the wells?'* (SRQ1), '*what is the physical quality of the groundwater discharging from the wells?'* (SRQ2 and '*what is the users perspective concerning the groundwater use?'* (SRQ3). In order to give an answer and a conclusion concerning the MRQ, the SRQ's will be answered in this section.

Of the total 78 communal wells reported by the Municipality of Cliza in 2010, 34 wells have been measured and have a high deviation in discharge values, varying from 1.5 till 22.5 l/s and the average discharge is 8.1 l/s. The deviation of these values can be explained by the pumping power of a well required to get a certain discharge from a certain depth. Annual discharges range between 59,305 and 399,168 m^3 and the average is 139,089 m^3.

Concerning the water quality of irrigation water, pH values (n=24) range from 6.5 till 8.6 and all values except one (pH=8.6) are in the range of general acceptable values for irrigation water. EC values (n=28) range from 290 till 1660 uS/cm, 75% of all values is considered non-saline, 25% is considered slightly saline and 0% is considered moderate or highly saline. Temperature values (n=26) range from 18.3 and 23.5 °C and all values exceed the critical value of 15 °C, meaning the temperature climate can enable high occurrence of coliform bacteria. Summarized, it can stated that the parameters pH and EC score good values on irrigation water quality but the temperature climate of the water can enable high occurrence of coliform bacteria with the risk of contaminating irrigated crops.

Concerning the water quality of drinking water, pH values (n=8) range between 6.5 and 7.7 and all pH values fall with the range of acceptable drinking water. EC values (n=10) range between 220 and 1025 uS/cm, 70% of the measured wells is considered non-saline and good for drinking water, the remaining 30% is considered slightly saline and only classifies as irrigation water. All values of turbidity (n=10) are below 5 NTU and are considered acceptable for drinking water. Temperature values (n=7) range from 18.3 till 23.5 °C and all values exceed the critical value of 15 °C. Overall it can be stated that pH and turbidity score good values on drinking water quality, slightly saline water occurs and the temperature climate can enable high occurrence of coliform bacteria.

The users perspective concerning groundwater use starts with the process of obtaining a well, which is done with support of the municipality and large scale government projects. Currently no permits or restrictions are in place concerning groundwater use. Wells are located with information of a geophysical study and users knowledge on the location and depth of salty zones. Access to water, water distribution, maintenance of infrastructure and wells and regular user meetings are organized through a WUO. All members of a WUO have equal water rights and in cases, people outside the WUO can obtain temporary water rights as well at costs 2 till 4 times higher than WUO members. Agricultural production consist of maize, potato, alfalfa and field beans. Farmers use the convenience of on-demand groundwater irrigation in the dry period to control the quantity of water for potato and beans since these are more sensitive for water logging than maize and alfalfa. 50% of the interviewees (n=27) could report active maintenance, 30% occasional maintenance and 20% stated no maintenance was done yet, since those wells started functioning recently. Concerning problems with a well, 25% of the users (n=20) mentioned frequent pump breakage, 20% mentioned pump control, 10% mentioned canal losses, 5% mentioned corrosion in the system and 5% mentioned a lack of maintenance as experienced problems. However, 40% stated to have no experienced problems. Perceptions on drinking water in terms of quantity and quality are both good since 80% combined stated the quantity is sufficient till abundant and 80% state the water quality is good. Perceptions on irrigation water are less positive in terms of quantity since 57% state they are lacking water, however in terms of quality the perceptions are good since 73% stated they quality of the water is good. Finally, the majority of the users state they want to have more water available and the minority mentions measures outside this scope and focusses on water saving measures as a future perspective.

6. DISCUSSION

In this chapter first the reliability of the of results will be discussed followed by an interpretation of the results to discuss its meaning. Then the results of this thesis will be compared with the global academic discussion concerning groundwater use, summarized in Shah et al. (2007) and finally the usefulness of this thesis and future recommendations will be discussed.

6.1 RELIABILITY OF RESULTS

The water quality measurements that have been executed consisted of one measurement per sampling site. This implies one weakness and one limitation: firstly it means that per site measuring errors cannot be detected since different samples cannot be compared with each other. Secondly Barcelona et al. (1985) state that hydrologic and chemical conditions vary both in time and space and that subsurface environment of groundwater is dynamic. Therefore it can be stated that the executed individual groundwater samples only provide a snapshot picture of the hydrogeological and chemical conditions that are present at the measured site. Another weakness of the measurement methods is that the EC measurement instrument is only calibrated with a solution of 1413 uS/cm while most of the collected data ranges below this value. The water quantity measurements were executed with a bucket of 30 or 45 liters and in cases of a high discharge value it only took between 1.5 and 3 seconds to fill the bucket which can make the measurement inaccurate. For example, if it takes 2 seconds to fill a bucket and an error is assumed of 0.5 seconds at the start and at the end, already an error of 50% (1 out of 2 seconds) can be assumed. The explanation of the deviation in discharge values is only investigated on the pumping power and pumping depth. In reality, multiple factors besides these 2 factors influence the discharge leaving a well, for example: the aquifer and subsurface characteristics, which have not been taken into account. Besides this, the annual discharges are calculated based upon the fact that the discharge per second is constant during the whole year and since aquifer characteristics vary over time so can this be the case for the discharge leaving a well. At last, farmers could indicate how many hours a pump functioned a day, the amount of days in one month and the amount of months per year that a pump functioned. Assuming this homogeneity in every day and month over a whole year affect the accuracy of the calculated annual discharge of a well.

Concerning the data analysis with literature the first weakness is that EC values are classified according to Rhoades et al. (1992),stating that EC values are expressed at a standard temperature of 25 °C and in this case all temperature values differ from 25 °C. Secondly, temperature values are compared with the critical value of 15 °C concerning the possibility of high occurrence of coliform bacteria stated by LeChavallier (2003). However in reality the occurrence of bacterial growth depends on a complex interaction of chemical, physical, operational and engineering parameters and no single factor alone like temperature can account for coliform bacteria occurrence (LeChevallier, 2003).

Questionnaires were done either directly by me with an average level of speaking Spanish, or information was translated from Quechua to Spanish or Spanish to English to me by Bolivian colleagues with an average level of speaking English. So it is very likely that significant information concerning all aspects of the users perspective was lost during the process of receiving information. Besides this, water users knew they were being interviewed by someone who was working together with the local municipality. Therefore the possibility that answers are modified and can have second motives in order to receive support should not be excluded.

6.2 INTERPRETATION OF RESULTS

The results of the water quality measurement are in line with the users perception concerning their water quality, since both drinking water and irrigation scored good on water quality parameters except for the temperature climate. On a local level the groundwater use is managed in a good way since water distribution and maintenance are organized through a WUO and for the sake of equity the board members of the WUO are changed regularly between WUO members. This argument can be even more strengthened since future risks of a well's malfunctioning are financially taken into account from money that is paid for the water. From a larger perspective, meaning: the whole watershed, this argument is different since right now there are no restrictions on water use and water supply (aquifer recharge) is not taken into account. Therefore the sustainability of groundwater use from a watershed perspective should be questioned. The fact that in the nearby Punata the groundwater level decreased 2.2 meters in one year (1), multiple farmers in Cliza had to place their pumps deeper in order to still have water (2) and the majority of the water users want to have more water available (3) strengthen this argument even more. Besides this, groundwater use trough wells is highly depending on the support of the municipality since the municipality pays between 60 and 85% for the construction of the well. A notable amount of this invested money is not used for profit since 42%, 85% and 50% of the production of maize, potato and alfalfa respectively are used for own consumption. These 3 crops cover 97% of the agricultural area in Cliza, so the main part of the crop production, enabled by municipality support, is used for own consumption and not for merchandise. Therefore the financial sustainability of the groundwater use for crop production should also be questioned.

Overall it can be stated that at a local level water use is managed good since it takes future risks into account, the sustainability of the larger scale watershed management should be questioned as well as the financial sustainability of groundwater use for the current crop production.

6.3 THE CASE OF CLIZA IN A GLOBAL PERSPECTIVE

The case of Cliza's groundwater use can be explained by the supply-push and demand-pull factors enabling the global groundwater boom mentioned in Shah et al. (2007). The first supply-push factor enabling groundwater use in Cliza is the fact that the local municipality directly, or through large scale government projects, the perforation and construction of a well subsidizes for 60 till 85%. The second supply-push factor that occurs is the availability of drilling technology through a variety of companies located in Cliza itself and Cochabamba. Besides these supply-push factors a very important demand-pull factor is the groundwater's capacity to provide on-demand irrigation which farmers in Cliza use to their benefit to irrigate water logging sensitive crops with groundwater in the dry season, meaning farmers can control exactly the quantity and timing of water they want to irrigate. Globally these supply-push and demand-pull factors have enabled a groundwater boom in all climate zones, from the growing to need to supply food for urban populations and this is the case in Cliza as well, even more since Renner and Velasco (2000) mention rapid population growth and increasing demand for irrigation and drinking water in the Valley of Cochabamba.

There is strong relationship between the case of Cliza and the global debate stated in Shah et al. (2007) concerning sustainable yield of aquifers since right now the supply-push and demand-pull factors are not limiting but enhancing groundwater use. At the same time Ortiz (2013) mentions that the groundwater table decreased 2.2 meters between November 2011 and November 2012 in the nearby Punata, located in the same watershed. It is debated that to manage groundwater resources properly an improved understanding of the aquifer has to be combined with an appreciation of the socioeconomic drivers of intensive groundwater use (Shah, et al., 2007). Cliza is highly depending on agriculture for their economy, agriculture is part of the culture of the area and 76% of the land use comprises of intensive agriculture, clearly indicating the socioeconomic drivers. Currently the socioeconomic drivers in combination with the supply-push and demand-pull factors are enhancing the groundwater use and the improved understanding of the aquifer is underemphasized.

6.4 USEFULNESS OF RESULTS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This study does not give hard facts on the water quantity, water quality or users perspective concerning groundwater use in Cliza. Rather, it gives a first indication of the current state of groundwater use in Cliza. This first indication is useful in order to come to sustainable ground water management where aquifer characteristics are combined with socioeconomic drivers and the water balance approach stated by Wright et al. (2000) can be applied. This study functioned as a first inventory of the demand side of the water balance approach.

It is recommended that an in-depth study on both demand and supply of water is done in the area of Cliza. This is essential to come to sustainable groundwater management, which implies that the socioeconomic needs are covered and the long-term deterioration of groundwater as a resource is prevented. It is also recommended that education is applied to the water users in the area to shift the focus from using more groundwater to the more effective use of groundwater, like sprinkler irrigation through a piped system. At last, it is recommended that the financial sustainability of the groundwater use in terms of financial input and output is investigated as well as alternatives that can increase the financial output, for instance: crop diversification.

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ANNEXES

ANNEX 1: INTERVIEW INVENTORY AND INTERVIEW USERS PERSPECTIVE (SPANISH)

I. Información del entrevistado

Nombre entrevistado:	Cargo:
Comunidad:	Fecha:
Observaciones:	

II. Información general del pozo:

Cuenta con informe técnico:	SI	NO	Responsable del Inf.Tec.	
Nombre del pozo:				Código pozo: Código GPS:
Coordenadas UTM:	X:	Y:	Z:	
Empresa perforadora:				
Año de perforación:	Estado:	EF	DF	FR

III. Datos técnicos del pozo:

Prof. Perforada:	Prof. Entubada:	Diámetro Pozo:	
Prof. Instalado de Bomba	Potencia Bomba :		
NE (mbbp):	ND(mbbp):	Stick up:	
Caudal diseño (l/s):	Caudal actual (l/s):		
Fecha medición:	CE (uS/cm):	pH:	Turbidez:

Datos de aforo				*Croquis sitio de aforo*
Lect.	Tiempo(s)	Volumen(l)	Caudal (l/s)	
1				
2				
3				
Prom.				

IV. Uso de agua, operación y mantenimiento:

Uso de agua:	Riego	AP	Mixto	Industria	Otros
Tipo de uso:	Comunal	Particular			

Nombre comunidades beneficiarias:	Nº Usuarios	Uso	Hr/acción	Costo (hr o m3)

Funcionamiento pozo	Hr./día:	Días descanso/mes:	
	Actual: De: ……….hasta:………..	Época estiaje: De: …………hasta:………….	Época lluvia: De: …………….hasta:………….

	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC
Funcio. Hr/mes												
Costo Bs/mes												

Problemas y dificultades del pozo………

FICHA DE ENTREVISTA

1. ¿Cómo fue la ubicación del pozo?

- Estudio geofísico. En que lugares o cuantos puntos)
- Decisión comunal o personal, conocimiento sobre zonas salinas

2. ¿Cómo fue la organización antes de la perforación de pozo y como fue el proceso hasta tener un pozo?

Nombre de la organización:………

- Cuáles son los actividades de la organización para el funcionamiento del pozo

Cargo	Funciones

3. Como se distribuyen el agua entre los usuarios (al inicio y actual), (epoca seca y epoca lluviosa)

4. Derechos de agua

   a. Formas de adquisición
   b. Variadad de derechos
   c. Expresion de derechos
   d. ¿Qué debe hacer el usuario para mantener sus derechos ala agua?.

5. Qué acciones de mantenimiento se han realizado (bomba, pozo, accesorios, tuberias)?

Fechas de mantenimiento (últimas dos fechas)	Empresa de limpieza o comunidad	Modificaciones				
		NE	ND	Prof Bomba	Pot . Bomba	Otros

6. Disponibilidad de agua
   a. A cuantos pozos es socio: Nº
   b. Nombres:

7. Producción agrícola

Cultivos	E	F	M	A	M	J	J	A	S	O	N	D	Riego (c/r-s/r)	Nombre pozo

8. La cantidad de agua de los pozos es suficiente para (los cultivos/consumo) □ falta □ suficiente □ abundante
    a. En qué época y/o para qué actividad se percibe escasez de agua?

9. Cuáles son sus percepciones sobre la calidad de agua? (sal, turbidez, contaminación, etc)

10. Cuáles son las acciones para mejorar la calidad (limpieza pozo, cloración, etc)

    Cuáles son las principales preocupaciones de los usuarios en relación a la disponibilidad y calidad del agua?

11. Qué tipos de información y conocimiento demandan los usuarios de los pozos (hidrogeología, diseño de pozos, sistemas de bombeo, etc.)?

12. Cómo ha variado el caudal de operación en el tiempo?

13. Cuáles son las visiones futuras sobre la disponibilidad y calidad de agua de riego o agua potable?

ANNEX 2: RESEARCH DATA

ID	X (UTM)	Y (UTM)	Z (m)	Name of the well	Community	State (RF: recent functioning	Year of perfora tion	Perfora ted depth (m)	Tube d depth (m)	Pump ed depth (m)	Diam eter (inch)	Pump ing force (HP)	Measurem ent date
P001	189101	8047774	2735	Flores rancho	Flores rancho	Functioning					6		10-4-2014
P002	189476	8050464	2732	Flores rancho	Flores rancho	Functioning	2006	73	69.5	36	6	10	10-4-2014
P046	189021	8049569	2739	Flores rancho 2	Flores rancho	Functioning							28-4-2014
P003	184807	8055605	2708	Villa Rosario II	Villa Rosario	Functioning	2012	42	38	36	6	1.5	10-4-2014
P004	187392	805248	2720	Villa Surumi I	Villa Surumi	Functioning	2002						
P005	186869	8053136	2718	Santa Lucia	Surumi	Functioning	2000	66	63		8		6-5-2014
P006	187301	8054228	2718	Santa Barbara	Huallpero Alto	Functioning	2013	35	32		6		17-4-2014
P007	187272	8054627	2718	Huallpero II	Huallpero Alto	Functioning	2009	63	55		6		15-4-2014
P008	186559	8054752	2714	los eucaliptos	Huallpero Alto	Functioning	2002	72	61.5	45	6	5.5	22-4-2014
P009	188186	8055115	2718	Kala Conto	Kala Conto	RF							
P010	188143	8054152	2713	Kala Conto	Kala Conto	Functioning	1999	90			6		15-4-2014
P011	187595	8055361	2715	Porvenir	Porvenir	Functioning	2013				6		15-4-2014
P012	187865	8055575	2714	AP Porvenir	Porvenir	Functioning	2000	105			6		15-4-2014
P013	188115	8055379	2722	Virgen de Copacabana	Porvenir	RF							
P014	187312	8055815	2718	1 de Octubre	Porvenir	RF	2013	45			6		
P015	186779	8055288	2721	San Iisdro el Labrador	Huallpero Bajo	Functioning	2005	52	50.5	39	6	5.5	15-4-2014
P016	186391	8055741	2716		Huallpero Bajo	RF							
P017	187223	8054666	2713		Huallpero Bajo	RF							
P018	186868	8055154	2713	Huallpero Bajo	Huallpero Bajo	Functioning		56	55	48	4	3	21-5-2014
P019	187684	8053662	2721	Santiago	Mosos Rancho	Functioning	2010	70	60		6		17-4-2014
P020	187318	8053829	2712	Mosos Rancho	Mosos Rancho	Functioning	1994	72	72	66	8	5.5	17-4-2014
P021	187881	8056601	2698	Lote 15 Barrio	Barrios Unidos	Functioning	2008	34	34	24	6	2	23-4-2014

				Unidos									
P022	187538	8056377	2716	Villa Florida	Pilli Cocha	Functioning	2000	30			4	2	23-4-2014
P023	188585.04	8054816.3	2714	Lote 15 Perez Rancho	Perez Rancho	Functioning	2008	60	60	24	6	5	
P024	189118	8054846	2718	Lote 14 Perez Rancho	Perez Rancho	Functioning	2010	60	60	25	6	5	23-4-2014
P025	188992	8054763	2726	Perez Rancho	Perez Rancho	Functioning	1999	70			6	3	24-4-2014
P027	187453	8050695	2728	Tercer Suyo	Chullpa	Functioning	2011	75	68	30	6	10	28-4-2014
P028	187307	8051110	2728	Vargas Rancho	Chullpa	Functioning	2005	75	68	30	6	10	28-4-2014
P029	187563	8050229	2732	Rajay Pata	Chullpa	Functioning	2000	65	45		6	10	29-4-2014
P030	187842	8049906	2737	San Marco	San Marco	Functioning	2004					5	
P031	188035	8050565	2733	San Marco	San Marco	Functioning	1970	80		36			29-4-2014
P032	187922	8049944	2741	San Marco 2	San Marco	Functioning	2010	65	65		6		
P033	185610	8049456	2748	Apayoma	Ayoma								
P034	186637	8049688	2731	Ayoma I	Ayoma								
P035	186869	8049691	2732	Ayoma II	Ayoma								
P036	187301	8049302	2737	chillijchi	chillijchi								
P037	190190	8053873	2718	Pozo A	villa 2 de agosto	Functioning							
P038	190104	8054611	2720	villa 2 de agosto	villa 2 de agosto	Functioning	2013	80	75		6		20-5-2014
P039	190295	8053754	2749	Pozo B	villa 2 de agosto	RF		73	70		6	7.5	6-4-2014
P047				villa 2 de agosto	villa 2 de agosto	Functioning							
P040	188522	8056223	2707	villa concepcion	villa concepcion	Functioning	2002	35	32		2	2	29-4-2014
P041	189043	8056462	2710	pozo2	villa concepcion		2003						
P042	188945	8055500	2710	pozo	villa concepcion		2000						
P048	189517	8056221	2710		villa								

					concepcion								
P049	189439	8056289	2710	pozo3	villa concepcion		2003						
P050	189267	8055601	2714	sistema de riego 1	villa concepcion	Functioning	2005	37			6		24-4-2014
P043	190981	8053127	2717	esperanza 1	60 Fanegad	Functioning							8-5-2014
P044	190728	8053354	2726	esperanza 2	60 Fanegad	Functioning							8-5-2014
P045	189648	8050972	2722	pozo 2	khochi lazaro	Functioning	2012	73	70		6	10	8-5-2014
P051	190130	8051509	2722	khochi lazaro	khochi lazaro	Functioning	2000				8	2	8-5-2014
P052				khochi lazaro	khochi lazaro	RF							
P053	190634	8050979	2747	khochi lazaro	khochi lazaro	Functioning					6		8-5-2014
P054	188244.47	8051089.56	2722	Nuevo Zenzano Banda Arriba	Zenzano Banda Arriba	Functioning	2009	74	50	30	6		6-5-2014
P055	188234.16	8051110.33	2720	Antiguo Zenzano Banda Arriba	Zenzano Banda Arriba	Functioning	1074	90		32	8		6-5-2014
P056	191699	8052672	2713		Wasacalle								
P057	191800	8052720	2741		Wasacalle								
P058	190804	8052231	2726	AP Antiguo	Wasacalle								
P059	190454	8052428	2723	AP Nuevo	Wasacalle		2012						
P060	191151	8052592	2721		Wasacalle	Functioning							
P061	187259	8053510	2718		surumi	Functioning		65		56	4		6-5-2014
P062	187123	8053396	2712	surumi	surumi	Functioning		78		56	6		6-5-2014
P063	189989	8053359	2720	Colectivo	Pozas Rancho	Functioning							
P064	189727	8053216	2724	Pozas Rancho	Pozas Rancho	Functioning	2004					5.5	28-4-2014
P065	189567	8054133	2717	21 de septiembre	Pozas Rancho	Functioning							29-4-2014
P066	189694	8054574	2588		Pozas Rancho		2002						
P067	189738	8053220	2721	Pozas Rancho	Pozas Rancho	RF							

ID	Q (l/s)	CE (uS/cm)	pH	Turbidity (NTU)	T (ºc)	Use (DW: drinking water)	User costs (Bs/hr)	Non-user costs(Bs/hr)	J	F	M	A	M	J	J	A	S	O	N	D
P001	12.18	220	7.3	< 5	23.7	DW			372	336	372	360	372	360	372	372	360	372	360	372
P002	8.08	362	7.6	< 5	22.2	Irrigation			0	0	0	0	0	600	620	620	600	620	600	0
P046	19.40	235	7.3	< 5		DW														
P003	4.50					Irrigation			0	0	0	0	672	648	672	672	648	672	648	0
P004						Irrigation			0	56	0	0	434	420	434	434	420	434	420	0
P005	12.48	750	7.88	<5	20.9	Irrigation	7	14	0	0	150	225	225	450	450	465	450	465	450	465
P006	9.09	564	7.42	< 5	21.9	Irrigation		20	0	0	192	0	372	360	372	372	360	372	360	0
P007	7.26	552	7.64	< 5	22.8	Irrigation	3	15	0	0	320	380	620	600	620	620	600	620	600	320
P008	4.44	980	7.11	< 5		Irrigation	3		0	0	352	330	713	667	690	690	667	690	667	0
P009																				
P010	9.94	480	7.97	< 5	22	Irrigation	5		0	0	240	225	580	560	580	580	560	580	560	0
P011	7.69	419	7.5	7.5	21.1	Irrigation	5		0	0	285	270	285	270	285	570	551	570	551	0
P012	2.00	567	6.71	< 5	19.3	DW	6													
P013																				
P014						Irrigation														
P015	4.43	523	8.03	< 5	21.9	Irrigation	3		255	510	510	510	510	510	510	510	510	510	510	255
P016																				
P017																				
P018	2.50	812	7.31	< 5	19.5	DW	1													
P019	2.63	504	8.03	< 5	22.8	Irrigation														
P020	3.12	334	7.94	< 5	22.5	Irrigation	5	20												
P021	2.19	910	6.92	< 5	18.9															
P022	1.54	1660	7.5	< 5	19.3															
P023						Irrigation	6	20	0	0	0	80	240	240	240	480	480	480	480	

P024	7.67	476	6.72	< 5	20.3	Irrigation	8		0	0	0	90	225	225	225	450	450	450	450	15
P025	1.78	570	7.21	< 5	20.4															
P027	15.50	689	6.55	10	18.3	Irrigation	5	8	0	0	0	3	270	540	540	540	540	540	540	
P028	13.94	782	7.02	<5	18.8	Irrigation	8	20	0	0	0	10	10	420	540	540	540	540	540	450
P029	7.12	1414	6.71	12.5	18.8	Irrigation	5	15	0	0	0	0	270	360	360	540	540	540	540	540
P030						Irrigation														
P031		831	7.2	<5	20.3	DW	10													
P032																				
P033						DW														
P034						Irrigation														
P035						Irrigation														
P036						Irrigation														
P037						Irrigation														
P038	8.68	621	6.81	80	20.3	Irrigation			0	0	108	360	372	360	372	372	360	372	360	0
P039	8.15	480		<5	20.7	Irrigation						8								
P047						DW														
P040	2.32	1025	6.47	<5	20.22	DW														
P041						Irrigation			0	0	0	330	330	660	660	660	660	660	660	0
P042																				
P048																				
P049																				
P050																				
P043	5.98	625	6.66	< 5	22.1	Irrigation														
P044	10.88	496	7.54	< 5	21.2	Irrigation														
P045	13.70	387		10	20.5	Irrigation	6	20	0	0	0	0	132	660	682	682	660	682	660	0
P051		451		< 5		DW														
P052						DW														
P053	20.00	655		< 5	20.9	Irrigation	6	20			110	330	330	682	682	682	682	682	682	682

P054	15.52	290	7.6	<5	22.5	Irrigation														
P055	22.50	290	8.6	<6	23.5	Irrigation														
P056						Irrigation														
P057						Irrigation														
P058	7.64	370	7.64	<5	23.5	DW	1.5													
P059		380	7.66	<5	21.4	DW	1.5													
P060						Irrigation														
P061	1.60	730	6.54	7.5	21.2	Irrigation														
P062	2.65	480	7.43	15		Irrigation														
P063						Mixed														
P064	3.60	516		<5	20.8	Irrigation			0	0	0	220	330	660	682	682	660	682	660	0
P065		469		<5		DW														
P066						Irrigation														
P067																				