Drinking water and urban growth: analysis of the integration of the land-use and water supply planning instruments in BioBio Region, Chile

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Abstract: The land-use planning process regulates the development of cities and significantly determines the future water demand. Thus, the planning of both water and land-use should be done in an integrated manner. The frequent problems of drinking water availability in urban areas around the world make us wonder whether this integration is actually happening. Through the analysis of the zoning and population densities proposed by the different instruments in representative urban areas in Chile, we study their degree of integration and find a lack of consistency between them. Recommendations to allow the desired integration are proposed.

Introduction

There is a growing concern about the protection, management and efficient use of water. It is estimated that projected water demand by 2030 will result in a global water deficit of 40% (Douglas, 2009). It is necessary to explore different solutions to mitigate the deficit and adapt to the negative effects of their scarcity. Although the main use of water globally corresponds to agriculture with about 92% (Mekonnen & Hoekstra, 2011), the growth of cities in the world has meant a steady increase in the demand for water. Traditionally, the land has been understood as a support for urban growth, and water as an input that must be supplied to allow this growth. The cities have expanded under the

XVI
World Water Congress
International Water Resources Association (IWRA)
Cancun, Quintana Roo. Mexico. 29 May- 3 June, 2017

assumption that water supply would undoubtedly be provided (Li et al., 2015), situation that leads to environmental problems and difficulties to ensure access to sanitation services, among others.
Related to drinking water, land use planning is key for promoting security access and service efficiency. Land use planning aims to provide the best spatial arrangement for the whole community, coordinating conflicting interests to seek the common good (Healey, 1997); It allows us to act and think at different scales of space, time and governance while performing at the local level, establishing the most favorable spatial arrangements for each specific place (Hürlimann & March, 2012; March & Henry, 2007). Therefore, land-use planning can allow the integration of considerations around water supply, from a general and local perspective (Angelo, 2001), to effectively manage the territory (Li et al., 2015). Moreover, land-use planning has the potential to foresee possible changes and their impacts on urban development (Hopkins, 2001; Hürlimann & March, 2012) in a proactive way to anticipate needs rather than in a reactive way that responds to the problems of the past. Integrating its processes with those of drinking water management, land-use planning could promote the development of cities with more sustainable growth patterns and water consumption in the long term (Gober et al., 2013), taking advantage of the existing sanitary infrastructure by delaying or eliminating the need for new projects that compromise the environment (Beckwith, 2014).

The problem of access to drinking water is common to urban areas worldwide. In Africa and Asia, 50% of the urban population (150 and 700 million people, respectively) has deficient access to a drinking water supply. In Latin America and the Caribbean, 30% and 40% of the urban population faces the same problem (Kajumulo 2003). In Chile many areas of urban growth have difficulties accessing the desired levels of drinking water, either due to lack of infrastructure, lack of availability of safe water throughout the year, or technical or financial difficulties to deliver the service (Aguirre, 2013). For example, locations such as Florida and Cobquecura in the Biobío Region, although declared urban areas, must be supplied by water tank trucks; In the first case, 50 trucks daily supply drinking water to 3,500 people living in the urban center (Bascur, 2013). The public actions to solve the problems of drinking water supply in the Region of Biobío have had a significant economic cost. Only for the water supply plan during the 2014 water emergency, approximately US$ 4.5 million were allocated (AMRBB, 2014). This situation reflects that the water supply cannot be taken for granted, and that the public strategies must guide urban growth to promote secure access and service efficiency. Although this region receives significant rainfall during the year and has numerous freshwater reservoirs, it is possible to find locations that do not have potable water distribution systems or wastewater disposal systems, as evidenced in urban areas which have not been able to adequately plan their urban territories.

Despite the existence of formal instruments for urban and sanitation infrastructure planning, water management and land-use planning in most countries are often not integrated (Li et al., 2015). This disconnection persists even though the evidence suggests that unsustainable land-use practices result in induced droughts and inadequate potable water supplies, limiting the development and growth of cities (Gober et al., 2013). This lack of integration has encouraged the exploration and analysis of how land and water planning are actually being performed. Carter et al. (2005) propose a normative model of integrated water and land management through the definition of evaluation questions and comparison criterion. Their model is applied to local planning processes in Canada. Additionally, Beckwith (2014) claims for more integration and states that the lack of coordination between water providers and land use planners is the norm and not the exception. He highlights a 27-question assessment tool developed to help evaluate the water and land use integration of a community plan in Denver, USA. As exemplified by the above-mentioned studies, the lack of integration between urban land-use and water supply planning represent a growing need for research.

In this study, we propose three quantitative indicators to evaluate the degree of integration of both the land-use and the water planning instruments. To identify the failure in the current interaction between the instruments, a set of nine questions are developed. Indicators and questions are applied to eight urban areas in Chile, and a lack of integration between the land-use and the water planning instruments is verified.

Methods

The degree of coherence between what urban planning proposes and the actual feasibility of supplying drinking water was determined through a qualitative and a quantitative analysis. A mixed method approach was selected as they are critical for public policy research (Brannen & Moss, 2012) and can provide with understandings that otherwise would not be possible to obtain with one method alone (London, Schwartz, & Scott, 2007). The quantitative analysis studies the degree of integration between the instruments for land-use and water planning, and the qualitative analysis contributes to understanding the causes of these results.

Planning instruments

As it happens in most of the countries, an urban Land Use Plan (LUP) regulates the cities future development. In Chile, this LUP contains particular studies, one of which is the Sanitary Feasibility Study (SFS). The SFS evaluates and warranties that the urban areas defined by the LUP will be covered by drinking water and sanitation services. Both instruments, the LUP and the SFS are considered in this study.

The drinking water and sanitation services are provided by private companies, which are enforced by law to provide the service within their so called Operational Territory (OT). The OT is an area mainly encircled within the urban boundaries, and its future development (maintenance or replacement of infrastructure, expansion, etc.) must be described in a Development Plan (DP). The DP is mandatory and has to be updated every 5 years. Figure 1 shows and example of the relation between the urban boundaries and the OT in one of the study areas. The DP is also considered in this analysis.

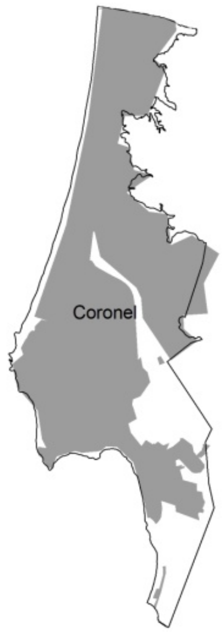


Figure 1. The Operational Territory (OT) of water supply companies (grey area) is encircled within the urban boundaries (solid line). Within the OT, companies are enforced to provide the drinking water and sanitation service. Source: Compiled by the authors based on GIS datasets of MINVU (2016) and SISS (2015).

Along with the LUP, SFS and DP of each of the urban areas under study, GIS datasets were used for numerical calculations.

Quantitative Analysis

The following indicators were designed to measure the spatial coverage of the water supply companies, in order to compare the degree of coherence between the actual operational capacity, the quantity of potential customers according to the expected growth in coverage and the projected population growth of regulatory plans. In all cases, the closes the indicator is to 1, the greater the degree of coherence between the planning instruments analyzed.

Indicator of Operational Territorial Coverage (OTC): this indicator relates the size of the OT defined by the DP with the size of the urban area defined by the LUP. It provides an indication of the spatial coverage of the water supply companies.

$$\text{OTC}=\frac{\text{Area of the OT}}{\text{Area of the urban zone}}$$

Indicator of the Potential Expansion of the Operational Territory (EOT): This indicator relates the number of residents currently served by the water supply company within its OT, with the number of potential residents allowed by the LUP within the urban area. This indicator represents the proportion of the maximum required capacity that is currently available.

$$EOT = \frac{\text{N° residents served by companies}}{\text{N° of potential residents in the urban area, based on LUP}}$$

Indicator of the Potential Demand within the Operational Territory (DOT): This indicator focuses on the OT, and relates the number of residents that the DP plans to serve in the future, with the number of potential residents allowed by the LUP within the OT. It represents the proportional difference of the projected amount of residents between the two planning instruments.

$$DOT = \frac{\text{N° residents planned to be served by companies, based on DP}}{\text{N° of potential residents within the OT, based on LUP}}$$

Qualitative Analysis

The quantitative indicators were complemented by a qualitative analysis to explore the possible causes that affect the numerical results. As proposed by Carter et al. (2005) and Beckwith (2014), among others, we based this analysis on a list of question, especially designed for this study, to explore the degree of integration of the planning instruments involved. For each indicator, three questions were evaluated (Table 1).

Table 1. Each indicator was asked three questions to identify the degree of integration between different planning instruments.

Question	Indicator		
	OTC	EOT	DOT
A	While defining the urban boundary, does the LUP consider the area defined by the DP?	While defining the urban boundary, does the LUP consider the population defined by the DP?	While defining the population density, does the LUP consider the potential population defined by the DP?
B	While defining the OT, does the DP consider the area defined by the LUP as urban?	While defining the OT, does the DP consider the population allowed by the LUP within the urban boundaries?	Does the DP consider the population allowed by the LUP within the OT?
C	Does the SFS consider the urban area defined by the LUP?	Does the SFS consider the population that the LUP allows within the urban boundaries?	Does the SFS consider the population that the LUP allows within the OT?

The answer to each question was one of the three categories, that is, Satisfactory, Improvable and Deficient. An answer was Satisfactory whether one of the instruments considers the relevant information of the other instrument for their own definition, where the relevant information depends on the particular indicator under analysis; Improvable whether the instruments only mention the relevant information of the other instruments, but this information does not affect the instrument definition; and Deficient whether one instrument does not even mention the relevant information contained in the other instrument.

Study Case

The quantitative and qualitative analyses described above were applied to eight representative urban areas in the Biobio Region, Chile. These urban areas were chosen based on the following criteria: (1) areas with a LUP no older than 15 years, because 15 years is the legal duration of the LUPs. Areas without a valid LUP were excluded, and (2) areas of different characteristics in terms of their complexity. In this sense, areas with a broad range of population (based on government classification) were chosen to obtain a representative study case. Table 2 shows the main characteristics of the urban areas considered.

Table 2. Main characteristics of the selected urban areas

Urban área	Year of enforcement of LUP	Population (2002 census)	Urban area (ha)	Operational territory (ha)
Lebu	2009	21.991	771	359
Los Álamos	2008	16.394	1.419	472
Cabrero	2009	18.037	2.456	411
Los Ángeles	2007	123.445	4.694	2.480
Coronel	2013	91.469	7.071	5715
Florida	2007	3.877	505	138
Cobquecura	2001	1.353	5.682	88
Quillón	2007	7.536	2.350	286

Source: Authors' own development, based on data from MINVU, 2016 and SISS, 2013.

Results and Discussion

The quantitative analysis suggests a lack of consistency among the instruments involved in the land-use and water planning process, both in terms of their spatial coverage and in terms of the number of residents they consider for the future. As shown in Figure 1, water supply companies must provide the service in an area (OT) smaller than the urban boundaries, reason why some people is not necessarily covered by the service. Figure 2 summarizes the different indicators for all the urban areas under study. The outer circle represents the maximum possible value of the indicator, while the shaded area represents its actual value.

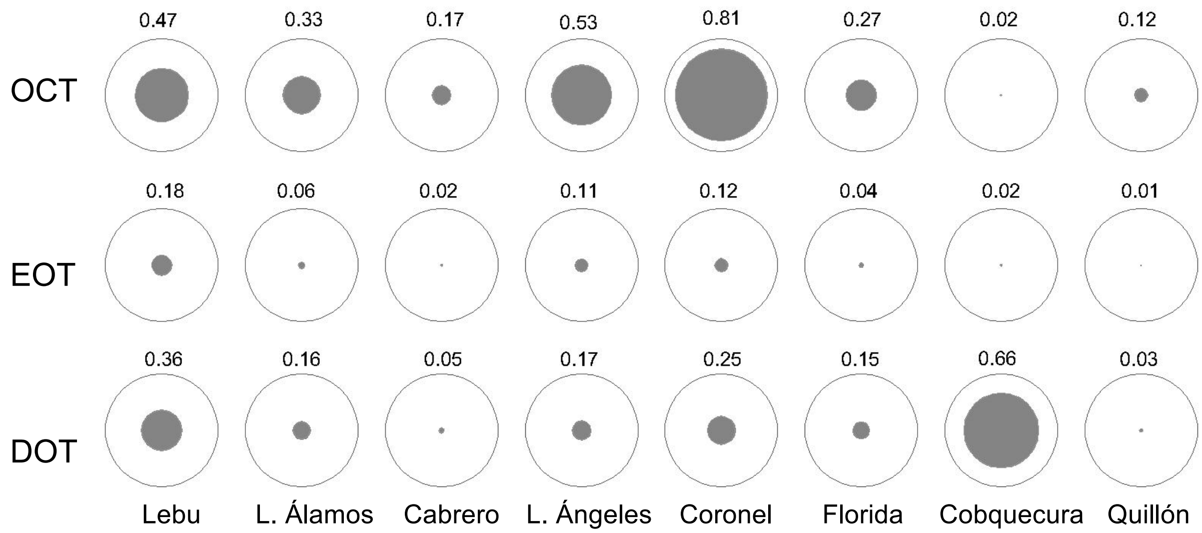


Figure 2. The low values of the different indicators suggest a weak integration between land-use and water planning instruments. Source: Compiled by the authors.

Although a threshold value for good indicators is not known, and it is part of a future research, it is clear the gap that exists between the current water supply capacities and the potential water demand. Considering that the higher the value of the indicator (close to 1) the better the integration between the planning instruments, the very low observed values suggest a weak integration between land-use and water planning

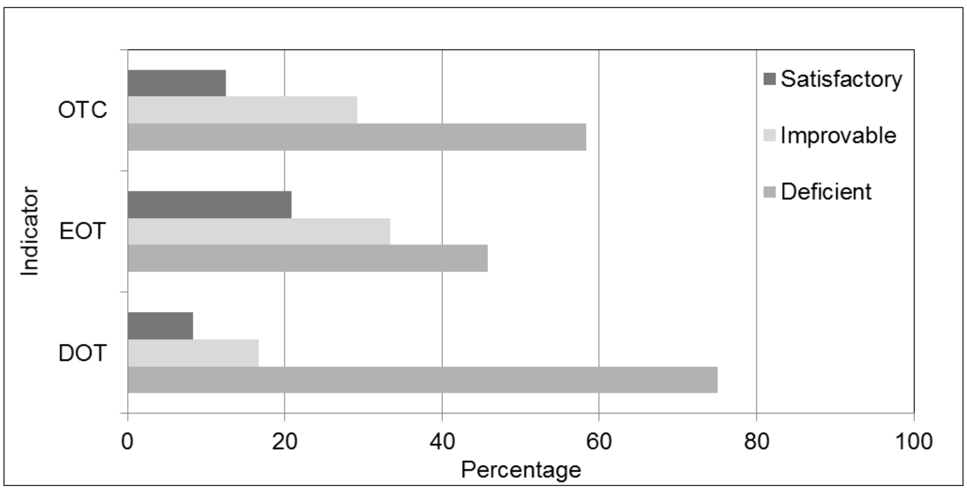
The OCT indicator considers the geographical coverage of the service, so in almost all of the areas under study most of the urban areas are not part of the operational territory of a water supply company. Outside of the OT, the water supply is not enforced. An extreme result for OCT is observed in Cobquecura (0.02), where the water supply company covers only the fiftieth part of the urban territory.

In terms of the potential users, EOT and DOT reflect the need for expansion that water supply companies might require in case the urban areas develop as allowed by the land-use plan. In EOT the expansion is over the actual number of users and within the urban area, so it represents the expansion of the current operations that is required to warranty water availability within the urban area. For example, the water company in Quillon would require to expand its current operations 100 times to fully warranty the service. DOT reflects more directly the degree of integration of the planning process, given that it considers the potential number of residents that both the companies and the planners project in an area. Except for Cobquecura (0.66), the low numerical values indicate that the both instruments, DP and LUP, plan the future of the cities based on quite different population projections. This fact certainly affects the chances to fulfil the future demand for drinking water.

From a qualitative point of view, the answers of most of the urban areas show a Deficient criteria of integration, and only a few answers were Satisfactory. In general terms, the planning instruments do not consider the assumptions or definitions that other planning instruments are doing when projecting the future of the cities. This disconnection affects the coherence between the future demand and the future supply for drinking water within the urban areas.

The weakest formal integration seems to happen within the OT of the water companies (Figure 3.a, DOT indicator). Only two out of the 24 questions (3 question x 8 areas) were Satisfactory (8%), while 18 question resulted in a Deficient degree of integration. This is surprising considering that water supply companies are enforced to provide the required drinking water within their OT, but they do not consider the population defined by the land-use instrument for the development plans.

a)



b)

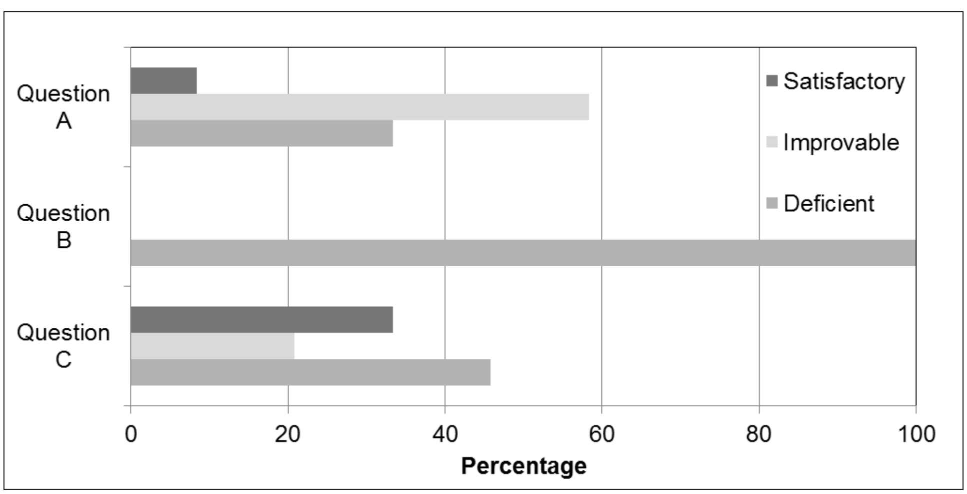


Figure 3. (a) Most answers regarding the three indicators were Deficient, and only a few answers were Satisfactory; (b) In all areas under study, the water supply companies not even mention neither the size of the urban area nor the potential population defined by the land-use plan.

Answers related to the integration between the DP and the LUP were all Deficient, reflecting that water companies do not consider, and are probably not even aware of, the size and potential population defined by the LUP. Under these circumstances, the planned capacity of the water supply companies may likely be exceeded by future water demand.

Conclusions

From the quantitative and qualitative analyses showed in this study, we can suggest that there is a lack of integration between the land-use and the water supply planning processes. The numerical values showed the magnitude of the inconsistences both in the geographical coverage of the water supply companies and in the number of potential residents that might need to be served.

The use of indicators resulted to be convenient to visualize the inconsistences between planning instruments. The definition of appropriate thresholds for the numerical indicators is left for further research. On the other hand, the use of evaluation questions as a complementary tool helped us to identify the cause of the lack of integration. We observed that the planning instruments do not consider, for their own definition, the relevant information contained in other instruments. This omission may the cause of the supply problems of drinking water in urban areas.

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