Eco-efficiency Assessment of Water Resource Management System in the Colombian Territories in the Caribbean Sea

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Summary

Many touristic islands around the world are facing a threat to the availability and the quality of the water resource because of problems in common like water scarcity during low precipitation seasons, overexploitation of the aquifers, intrusion of the sea water into the aquifers and lack of wastewater treatment plants. The goal of this research is to present the preliminary results of the evaluation of the eco-efficiency of the water resource management in the San Andres island territory in the Caribbean Sea. The results of this research not only help to give recommendations to the stakeholders to improve the sustainability of the water resource management, but also, it helps to create a research framework to study other case studies about the water management in islands in developing countries worldwide. This research is funded by the Research Unit and the Faculty of Civil Engineering of the “Universidad Santo Tomas Seccional Tunja, Colombia”.

Keywords: Water management, Groundwater Management, Caribbean Islands.

Introduction

Groundwater is a global, important, valuable and renewable resource, which is under threat of degradation both by contamination and inappropriate use. The management of this resource must be carefully planned in order to guarantee its availability for future generations. Worldwide, the sustainability of groundwater resources is associated with the policies that influence the use of water and soil, and this issue is one of the main challenges in the water management (Morris et al., 2003). Therefore, the management of these natural resources within a territory of a watershed or catchment is crucial to guide and coordinate management strategies for the sustainable development, considering the environmental, social and economic context. The groundwater is a complex resource and the studies about water availability and its quality are very difficult to develop (Lord & Kenney , 1993). There are studies about the groundwater management in cities, rural areas, small towns and agriculture, which summarize the problems in excessive exploitation, inappropriate or uncontrolled activities at the land surface and the change in land use (BGS, 1996; BGS, 1997). In addition, global warming has affected the sea level which has had an increasing effect on shoreline erosion, inundations, salinization, sediment movement, changed wave regime from overtopping of reef surfaces and changes in the estuarine dynamics which somehow have an effect in the availability and quality of groundwater (Nunn, 2013). San Andres Island is a Colombian territory in the Caribbean Sea with an extension of 26 km^2, a population of 76.000 inhabitants and a fluctuation of 950.000 tourists. According to the Corporation for the Sustainable Development in the Department of San Andres, Providencia and Santa Catalina (CORALINA), 85% of water supply is taken from the aquifer, a situation that requires an appropriate water management strategy in order to have a sustainable management of this resource (CORALINA, 2000). The purpose of this paper is to make an assessment of the environmental problem in order to carry out a sustainability assessment of the groundwater management in the island.

Methodology

As a first step, the status quo of the water management in the island was studied based on the water balance. For this purpose the Material Flow Analysis (MFA) was used considering all the inputs, outputs, processes and flows within the water management system in the island territory. The data to build up the system was taken from the public documents reported by the CORALINA. In a second phase a sustainability assessment was performed based on the environmental impact in order to establish a series of parameters to build up a system of indicators to assess the sustainability of the system which belongs to the second phase of the research project. This phase was based on the European project EcoWater (Levidow, L., 2014), in which the eco-efficiency was determined, identifying the use of the water resource, the environmental impact, and the value of the resource in the whole value chain. This part of the research is still under construction.

Results and Discussions

a) Status Quo of the Groundwater Management in San Andres Island

Material Flow Analysis is a simple methodology that helps to make a mass balance of of the water resources (Baccini, P. & Brunner, P., 2012). This method was applied in an attempt to understand the water balance in the territory of San Andres Island with the purpose of assessing the different processes and flows feasible to be improved in order to have a better sustainable economic exploitation of the island. The system is composed of 12 processes and 19 flows. There are three initial input flows such as precipitation, intrusion and the seawater, which flow through the soil and subsoil. This water is used by the population after a water treatment in the legal wells and it is used untreated in the illegal wells. After the use of the water resource, the wastewater is collected in the septic tanks and sewage system and finally it is discharged into the sea. The figures 1 to 3 explain all the water balance in the island territory and tables 1 and 2 explain the data collected to build up the system.

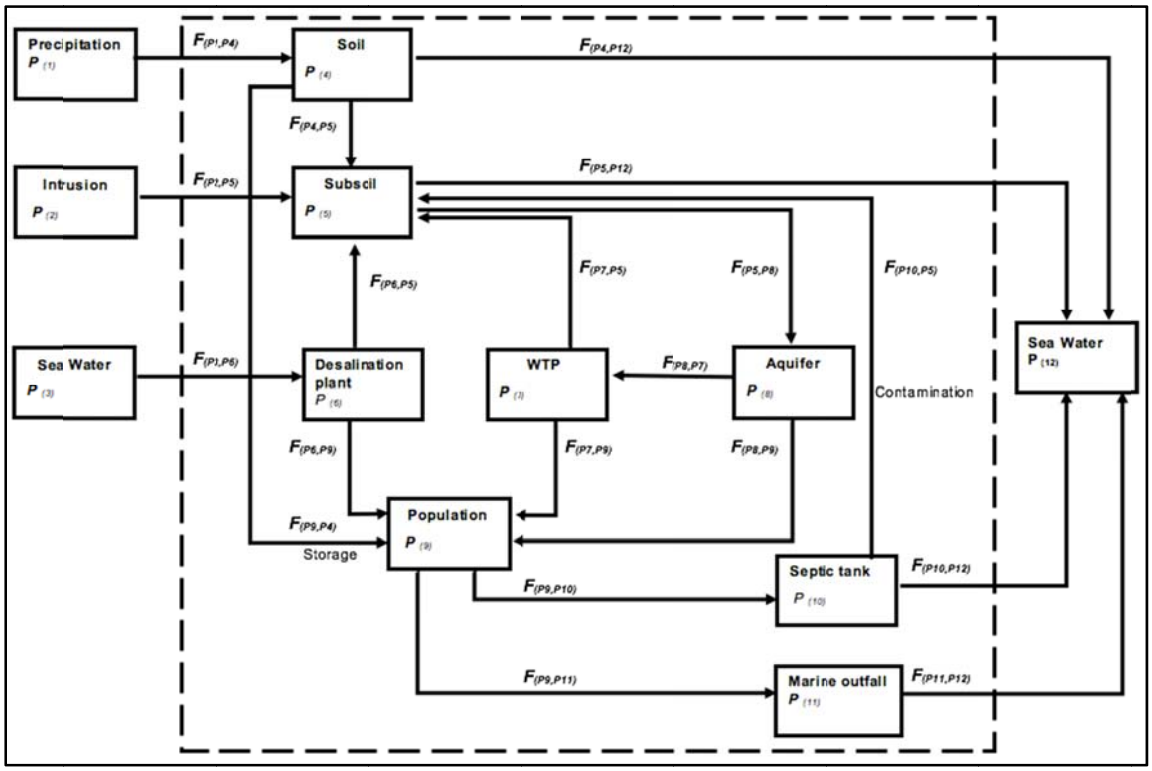

Figure 1: Water Balance System in the San Andres Island Territory.

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Table 1: List of processes in the water resource management system

Symbol	Processes	Quantification[#]
P_1	Precipitation	1900 mm/y
P_2	Intrusion	0.007 m^3/s
P_3	Sea Water	2440 m^3/day
P_4	Soil	Surface Area: 26 km^2
P_5	Sub-Soil	Not established
P_6	Desalintation Plant	2440 m^3/day
P_7	WWTP	Estimated discharge: 40 l/ s
P_8	Aquifer	Watershed Surface Area: 4.3 km^2
P_9	Population	65.627
P_{10}	Septic Tank	10.266 Septic Tanks
P_{11}	Marine Outfall	Not established
P_{12}	Seawater	Not established

#: The data was obtained from CORALINA (Corporation for the Sustainable Development in the Department of San Andres, Providencia and Santa Catalina) and PROATIVA, the local firm in charge of the water resource management.

Table 2: List of flows in the water resource management system

Symbol	Flows	Quantificación
$F(P_1.P_4)$	Precipitation	1900 mm/y
$F(P_4.P_{12})$	Surface Runoff	1.485 m^3/s
$F(P_4.P_5)$	Infiltration	480 mm/y
$F(P_5P_{12})$	No Domestic Use	0,044 m^3/s
$F(P_9.P_4)$	Storage	0.015 m^3/s
$F(P_2.P_5)$	Intrusion	0.007 m^3/s
$F(P_5.P_8)$	Recharge	0,040 m^3/s
$F(P_7.P_9)$	Groundwater Capture Wells	58 wells
$F(P_8.P_9)$	Surface Water Capture Points	600
$F(P_3.P_6)$	Sea Water	2440 m^3/día
$F(P_6.P_9)$	Distribution	Water Network and Water Cars
$F(P_7.P_9)$	Distribution	Water Network and Water Cars
$F(P_9.P_{11})$	Wastewater Network	Network Inventory
$F(P_9.P_{10})$	Septic Tanks	Network Inventory
$F(P_{10}.P_5)$	Contamination	Samples

#: The data was obtained from CORALINA (Corporation for the Sustainable Development in the Department of San Andres, Providencia and Santa Catalina) and PROACTIVA, the firm in charge of the water resource management.

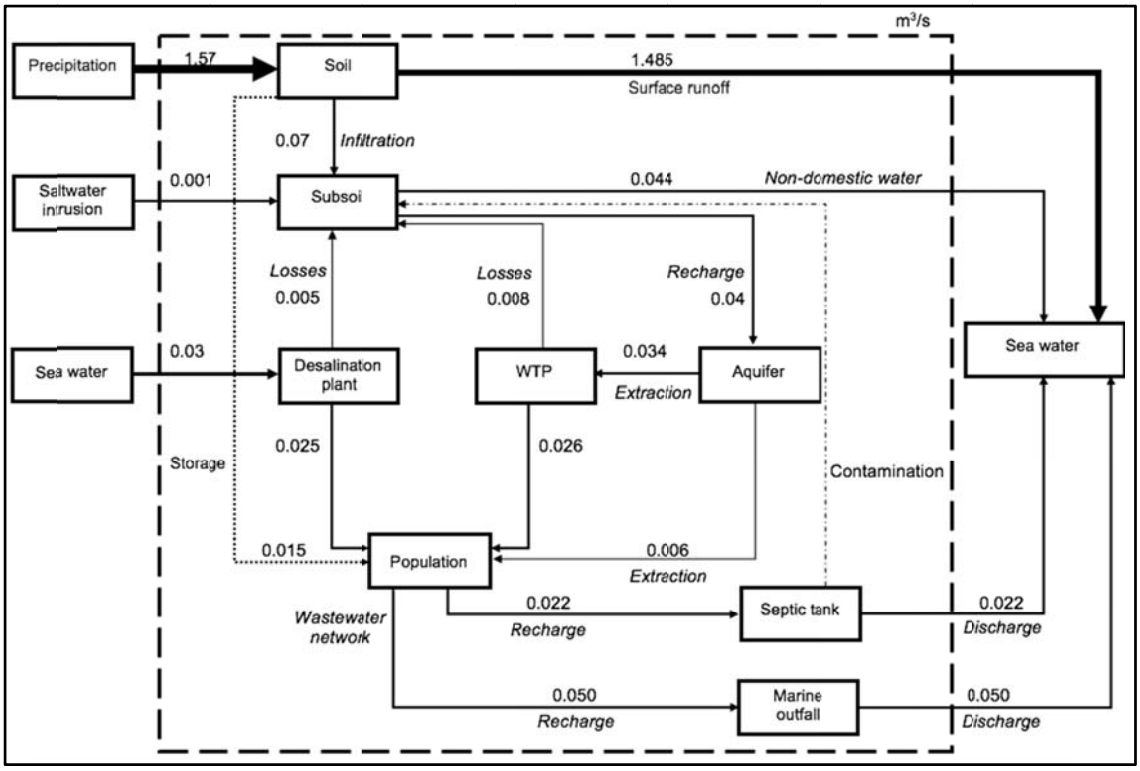

Figure 2: Water Balance System in the San Andres Island Territory in terms of m^3/s.

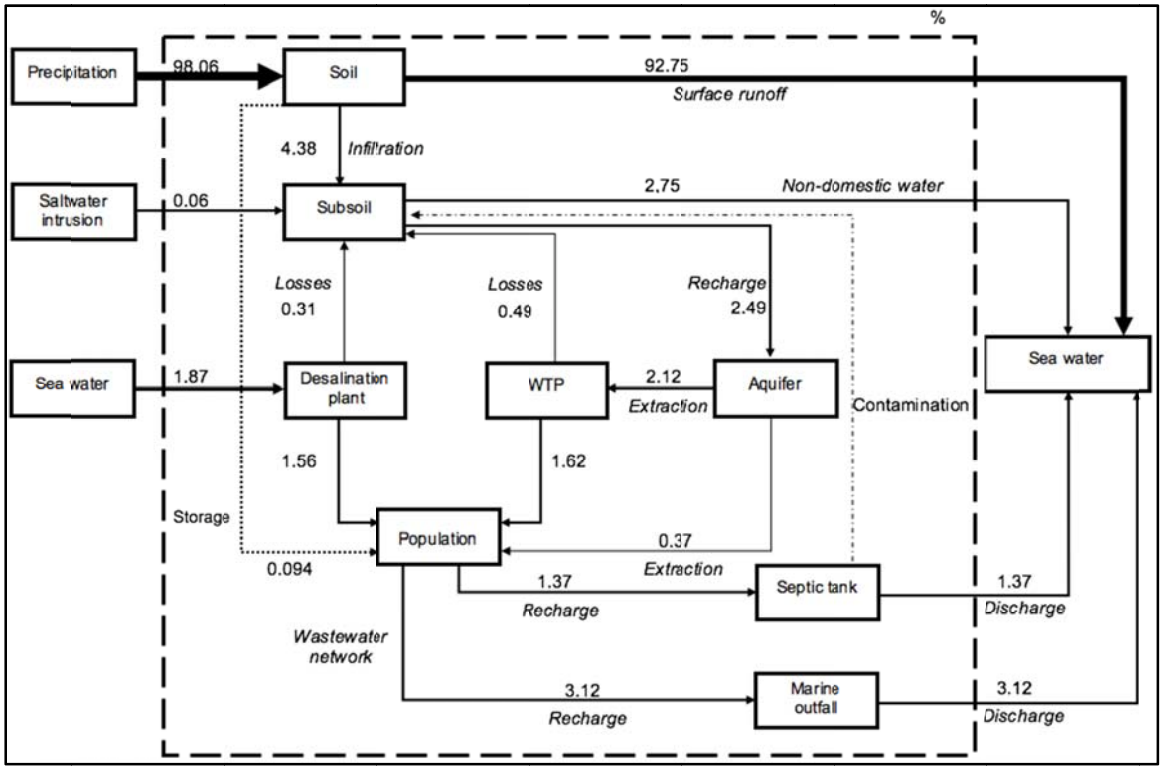

Figure 3: Water Balance System in the San Andres Island Territory in terms of %.

Once the system was built up, the relevant processes that have an environmental impact, and therefore, they influence the sustainability of the system. These processes are discussed below:

Precipitation: This is in one of the main sources of water in the island territory and there is a natural recharge of the aquifer depending on the magnitude, intensity, duration and distribution of rainfall. The rainy season starts on May until November – December, and it oscillates between 121 and 307 mm per month. Only 17% of this rainfall is used by the population. Because of the changes in the land use because of the extension of the urban area as well as the climate change, the recharge of aquifers is not homogenous, which creates an irregular exploitation of groundwater because of the constant water extraction to fulfill the demand of the population (CORALINA, 2014).

Desalinization: This process consists of the separation of dissolved salts form the sea to produce drinking, irrigation and industrial water (Medina, 2000). The island has a desalination water treatment plant based on reverse osmosis. However, there are some issues about the cost and maintenance of this technology as well as the environmental impact of the final discharge of the brine (Coralina, 2000).

Extraction Capacity: There are 17 legal wells which comply with the regulation of the Technical Regulation of Drinking Water (MED, 2000) about the water quality for drinking. However, CORALINA reports 5900 illegal wells used by the residents in different points in the island. Therefore, there is a complex situation to regulate the water extraction to reduce the risk of intrusion (CORALINA, 2000)

Water Quality: From the total amount of groundwater extracted for consumption, only 1% is considered as drinking water. This water extracted from the aquifers is treated by means of the processes of flocculation, filtration, disinfection, storage and final distribution. However, the water extracted from the 5900 illegal wells is not treated and it is consumed directly by the population in the island (CORALINA, 2015).

When the levels of water extraction are over the recharge capacity of the aquifers, this results in an overexploitation of the water resources, and in consequence, there is an intrusion of the sea water into the groundwater (Espinoza & Molina, 2005). In the present, there is no intrusion of the sea water but under the present exploitation of the aquifer and the increasing water demand by the tourism industry, there is a high risk of intrusion of sea water into the aquifer (CORALINA, 2000).

Marine Outfall: The wastewater in the island that comes from domestic use is discharged in the marine outfall at a rate of 3.12 l/s. This wastewater is collected both from the sewage system and the septic plants. The wastewater from the septic tanks is emptied by tank cars and then it is discharged in the marine outfall (CORALINA, 2000).

b) Sustainability Assessment of Water Management

There are three aspects that affect the sustainability of the water management. These are the overexploitation of the aquifers, the tourism industry and the climate change. Studies have showed that aquifers next to the coast present a risk of seawater intrusion (Batlle, 1998) and in general all the wells are overexploited which increase this risk. If there is seawater intrusion, this might create a negative environmental impact because the water quality is affected and to recover the water quality, the water treatment might require a more complex process (Espinoza & Molina, 2005). Even though, there is a strategy to pump groundwater into the aquifer, this measure is not sustainable in the long term because of the increasing water consumption by the tourism industry. A second problem is the tourism industry which has an increasing tendency and this issue results in a higher demand of water resources. As the economy of the island depends on this industry, there is a complicated management and the potential regulations for the water exploitation are difficult to be implemented. Finally, the climate change is affecting the rainfall regime which increases the soil erosion, and therefore, the water infiltration into the aquifer. These aspects suggest that to address this problem, it is crucial to develop regulations about the use of groundwater, establishing strict controls in the exploitation, and developing strategies for the aquifer protection.

c) Eco-efficiency of Water Management in the San Andres Island

Once the water use system was analyzed, the next step in the research is to assess the eco-efficiency in the use of the natural resource taking into account the economic benefits and the environmental impact with the purpose of lowering the ecological burdens (Levidow, L., 2014). In the structured system, the value chain of the water resource must be evaluated based on the water quality and the technologies implemented to improve it. Because the technologies increase the cost of water treatment and the scarcity of the water resource increases its value, these are issues to consider in order evaluating the eco-efficiency. This eco-efficiency assessment will be presented during the oral presentation in the XVI World Water Congress and a paper which is under construction to be published.

Conclusions

Once the water resource management system for the San Andres was understood and the environmental impacts are established, the next step in the research Project is to propose an integrated strategy that takes into account the different stakeholders involved in the system. Even though, this phase requires further research, from the water balance system and the aspects that influence the sustainability, it is concluded that there is an increasing water resource consumption from the aquifer, and this issue must be regulated in order to stop the overexploitation and therefore the seawater intrusion. Also, other water sources must be considered like the rainfall and the implementation of a more inexpensive seawater treatment for the desalination. Because the economy depends on the tourism and this plays an important role in the environmental system, this can sustain the research, development, and implementation

of technologies that improve the sustainability problem of the water resource management.

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