Groundwater availability and evolution of seawater intrusion in overexploited aquifers in arid zones under climate change scenarios.

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INTRODUCTION

In arid and semiarid zones where droughts are common, water resources are scarce and highly sensitive to anthropogenic activities. With demographic and economic growth, the aquifers are facing increasing pressure through an augment of water consumption, which generates extractions higher than the natural recharge. The overexploitation of aquifers in arid zones generates less availability per capita and a gradual loss of water quality. Under the predicted climate change scenarios (less winter rainfall, increase of evapotranspiration, extension of dry season, sea level rise), the situation would be expected to worsen. As a result, the availability, coverage and access to water will be at risk, in violation of the human right to water.

STUDY AREA

For this investigation, two study areas were selected: Valle de Santo Domingo aquifer (VSDA) and San José del Cabo aquifer (SJCA) (Fig. 1). VSDA has been overexploited since the early ´50s , due to agriculture activities and pumping of ~500 wells (Wurl e Imaz-Lamadrid, 2018; Wurl et al. 2018). Elevated values of salinity and depletion of water levels have been reported (Wurl e Imaz-Lamadrid, 2018; Wurl et al. 2018). SJCA is overexploited as a result of the growing touristic industry of Los Cabos. Water levels have decreased in recent years and surface water bodies have been affected by the discharge of gray waters (Wurl & Imaz-Lamadrid, 2006; Imaz-Lamadrid et al. 2019). Both cases have deficit in their water balance reaching 30.1 and 5.9 million m^3 (DOF, 2018).

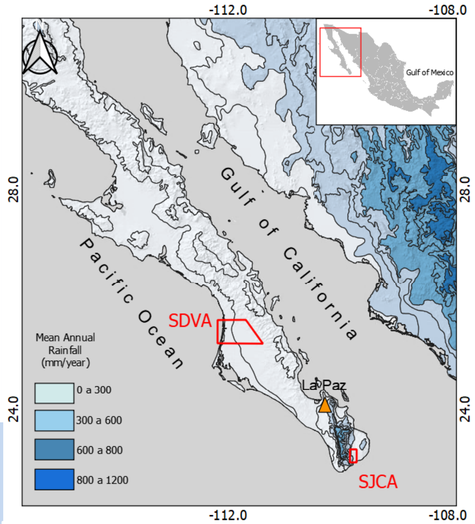
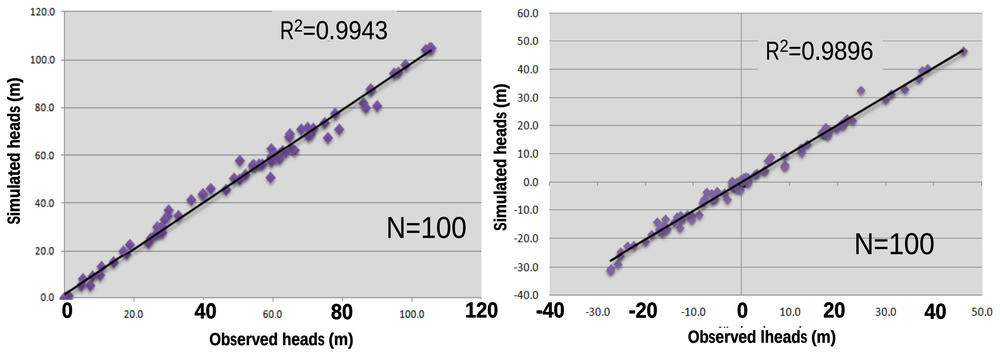


Figure 1. Location of study areas.

METHODS

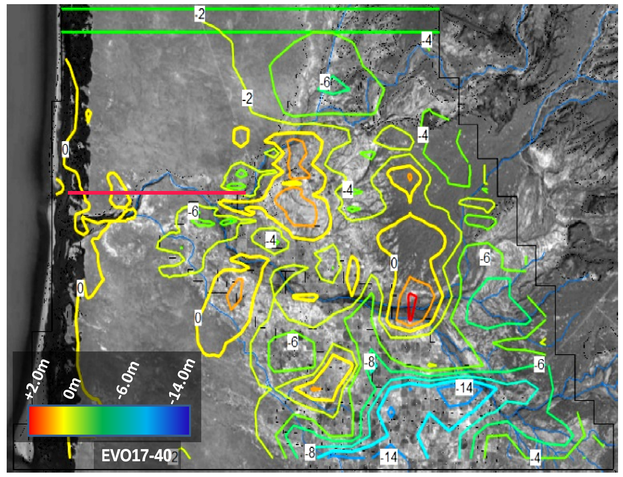
According to different sources, it is forecasted that winter rainfall will be reduced in a range of -10 to -35%, while summer rains will increase by up to 10%. Evapotranspiration will increase in a range of 2.6 to 7% and sea-level rise could be expected in a range of 0.2 to 2m for the year 2100 (Imaz-Lamadrid et al. 2019). Using this data three scenarios were defined actual (no climate change), conservative and extreme. Then, two tridimensional groundwater models, coupled with streamflow and seawater intrusion simulations were developed using Model Muse software. Five layers were modeled for SJCA and three for VSDA. The variables necessary for the simulations were obtained from various sources or generated for this study. The calibration process was performed simulating 8 years, each one divided into three periods: Dry season (180 days), wet season (60 days), and winter season (125 days)Models were adjusted and calibrated (Fig. 2). Then, climate change scenarios were introduced and simulations were performed for the near future (2040). Maps and sections were created using model results.

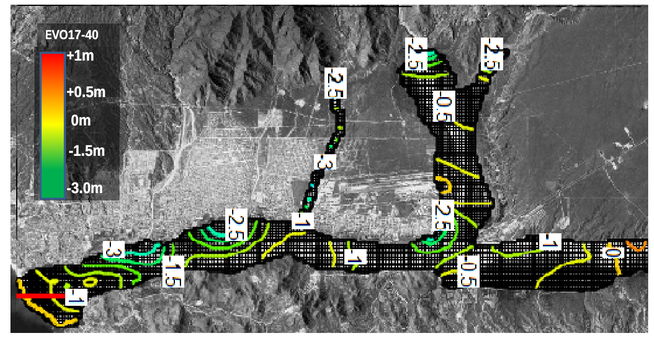
Figure 2. Calibration of the models using 100 control points. Both models have a good correation between simulated and observed values.

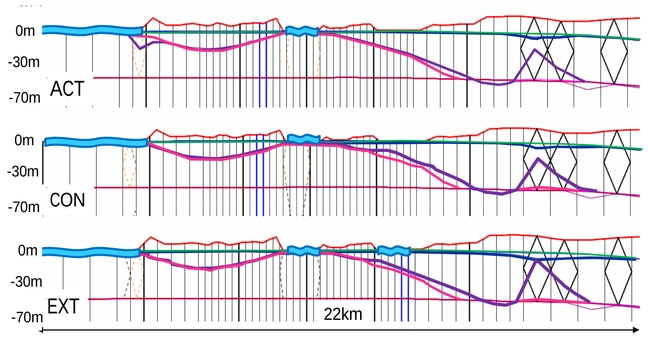


RESULTS

Results indicate that under different climate change scenarios, the recharge of freshwater (in situ rainfall and streamflow) will be reduced; therefore, groundwater levels will continue depleting and seawater intrusion will advance inland, increasing salinity near the coast. For VSDA, the depletion of water levels will be in a range of 0 to -14m while the advance of seawater wedge will reach 5.2km, generating an upconing effect in wells located near the ocean. On the other hand, in SJCA, the evolution of water levels will be in a range of 1 to -3m. The reduction of water levels near the coast will modify the inflow of freshwater to San Jose Lagoon, resulting in an advance of 900m of seawater into the lagoon and as an underground intrusion (Fig. 3).







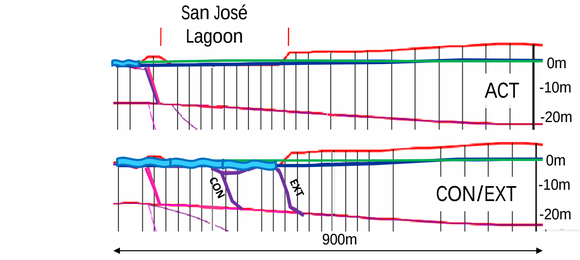


Figure 3. Evolution of hydraulic heads and seawater intrusion for the period 2017-2040.

Sea/Ocean
Water level 2017
Water level 2040
Seawater intrusion 2017
Seawater intrusion 2040

DISCUSSION AND CONCLUSION

In arid areas such as northwestern Mexico, climatic conditions in conjunction with industrial activities are increasing pressure on groundwater resources which is the main source of water for consumption. The climate change scenarios, together with population and industrial growth, will generate greater demand for water in the near future. Given this scenario, it will be difficult for governments and institutions to comply with respecting the fundamental right to water. Hence, it is essential to use methodologies such as the one we present in this work, in order to design actions that allow safeguarding the water resource for the future.

In the case of VSDA and SJCA, it is recommended to limit water pumping as well as the installation of managed aquifer recharge techniques to increase infiltration. The use of desalination plants could provide an additional flow to satisfy water demand; however, its implementation is expensive, and eventually, they can impact the ocean environment, especially in those areas with low oceanographic dynamics.

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