Chiquitania rural water supply

Considering decentralized water infrastructure and land use change in hydrologic analysis

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The Chiquitano dry forest in Bolivia is one of the largest and last remaining dry forests in the world, and is facing the interrelated threats of megafires and deforestation. These threats mainly result from rapidly changing land use that creates new pressures on natural resources from both agricultural and urban users. This includes increasing stresses on surface and groundwater resources, such as lakes, rivers and aquifers, which are evolving with the changing landscape.

To evaluate these threats and develop local expertise to support long-term water resource planning in the region, SEI has begun working with essential key actors, including regional authorities, the Ministry of Environment and Water (MMAyA), researchers at the Universidad Autónoma Gabriel René Moreno - Santa Cruz (UAGRM), and the Foundation for the Conservation of the Chiquitano Forest (FCBC). Such outreach has been concentrated in the Santa Cruz Department, where the vast majority of the Chiquitano dry forest is located.

Chiquitano dry forest hydrology and setting

Much of the environmental work until now has focused on the changes caused by increasingly damaging forest fires in the region. However, little is known about the effects of the simultaneous land and water use changes occurring on local hydrologic and ecologic systems. Much of the land and water use changes are being driven by ongoing agricultural expansion of pasturelands for cattle grazing and increasing municipal demands to support such expanding development.

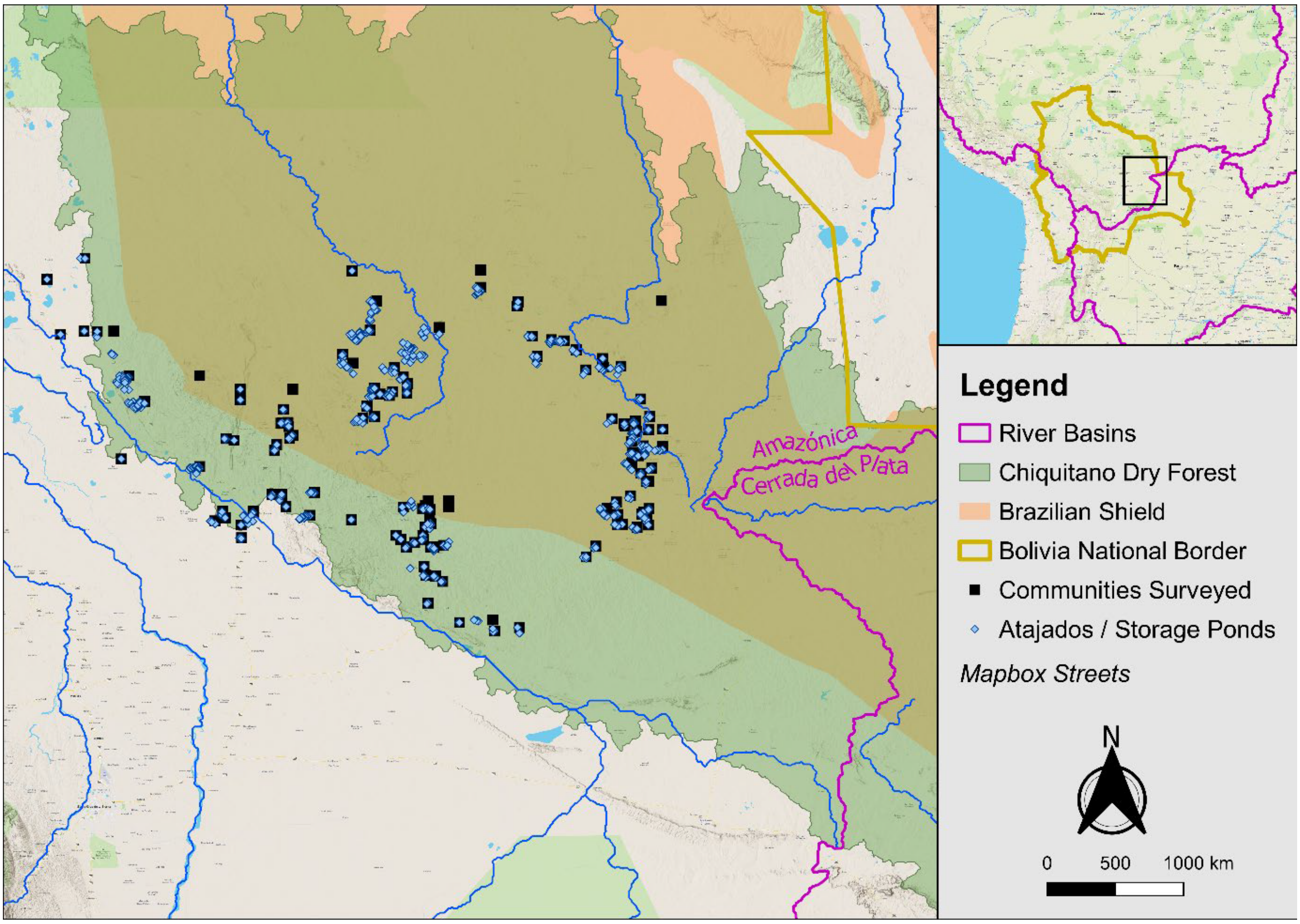
Straddling the Amazon and La Plata river basins, the Chiquitano dry forest covers about 89 000 square miles (Landivar, n.d.).

Hydrology in the region generally depends on the underlying geology, which is characterized by deep alluvial sediment originating from the Andes in the south and east, and bedrock formed by the Brazilian Shield in the north and west. The region of the Chiquitano dry forest lies mostly atop the Brazilian Shield, a geologic formation characterized by aquifers consisting of fractured bedrock or locally defined pockets of younger sedimentary basins, making them generally variable and hard to characterize.

The majority of recharge to local streams and rivers comes from precipitation, with average annual precipitation ranging from 1,300 mm over the Brazilian Shield to around 500 mm per year along the plains, and the majority of the rain is concentrated in the summer months from December to March. We used the Water Evaluation and

IMAGE (ABOVE):

Figure 1. Communities sampled by SEI partners at UAGRM in the Amazon River Basin section of the Chiquitano dry forest in the Santa Cruz Department of Bolivia. Brazilian Shield data from Schenk et al. (1998).



Planning tool (WEAP) to model the surface water balance in the catchments covering the Chiquitano dry forest from 1980 to 2015. Results indicate a collective streamflow of 5,220 cubic metres per second, or m^3/s (184,358 cubic feet per second, or cfs) on average during the wettest month of February, 198 m3/s (6,990 cfs) during the driest month of September, and an annual average of 1,677 m^3/s (59,227 cfs). These catchments contain 727 localities with a combined population of 232,793 people and provide water resources to thousands more downstream users and ecologically sensitive areas.

In addition to domestic water users, agricultural water users make up an increasingly large portion of the region's water demand. For example, according to Fundación Amigos de la Naturaleza, in the San Ignacio de Velasco district, which is representative of the forest region more generally, annual rates of deforestation increased from 30 square kilometres (km^2) per year in 2005 to 210 km^2 in 2018 (de la Vega-Leinert, 2020).

As urban and agricultural development in the region expands to what are currently very rural towns and municipalities, water supply infrastructure will evolve to fit the needs of the communities. Already, regional governments have fielded reports of increasing groundwater pumping and unregulated water infrastructure, causing alarm about the availability of surface water and groundwater resources for all.

Sampling campaigns to understand rural hydro-social components

To better characterize the region's water supplies and infrastructure, researchers at UAGRM carried out a two-pronged sampling campaign in the Amazon and La Plata river basins (Figure 1). Through a combination of remote sensing analysis (Figure 2) and in-person verification (Figure 3), surface water storage and groundwater wells were identified in the communities sampled. Our partners verified 212 surface water storage ponds, locally known as *atajados*, through the sampling campaigns, amounting to about 584 000 m^3 (473 acre-feet), or about 234 Olympic swimming pools, of water storage.

Following the campaign, we used remote sensing in the communities sampled to identify additional water storage. We identified a total of 31.6 million m^3 of storage in unlined artificial storage ponds, the vast majority of which serve as cattle watering ponds. The artificial surface storage identified represents 18.7% of the full natural flow of the surveyed catchments during the driest month and is not currently represented in hydrologic models of the region. In addition to the artificial ponds identified by remote sensing, we identified about 51.4 million m^3 of natural lakes and ponds in the communities studied that are also used for domestic, agricultural and fishing purposes.

Figure 2. An example of some of the atajados (water storage ponds) developed for cattle watering and domestic water supply in areas that were formerly Chiquitano dry forest.

Figure 3. Photos from the in-person verification of atajados developed for cattle watering, domestic water supply and fishing in areas that were formerly Chiquitano dry forest. (Photos: © SEI)

Furthermore, we verified 361 groundwater wells in the communities (Figure 4), more than half of which have been drilled since 2000. As seen in the photos taken during the campaign, much of groundwater extraction is done in shallow wells or with manual pumps. However, the number and flow rate of private wells for large agricultural users and municipal wells with electric pump systems are increasing. Of the 146 identified wells with electric pumps, more than one-third were drilled in the last 10 years and have an estimated capacity of 257,437 m^3/month (209 acre-feet/month), with many more unsurveyed, indicating that well drilling is active and increasing as the region develops.

Figure 4. Groundwater wells visited in the sampling campaign of the Amazon River Basin section of the Chiquitano dry forest in Bolivia's Santa Cruz Department include shallow wells, and manual and submerged pump systems. (Photos: © SEI)

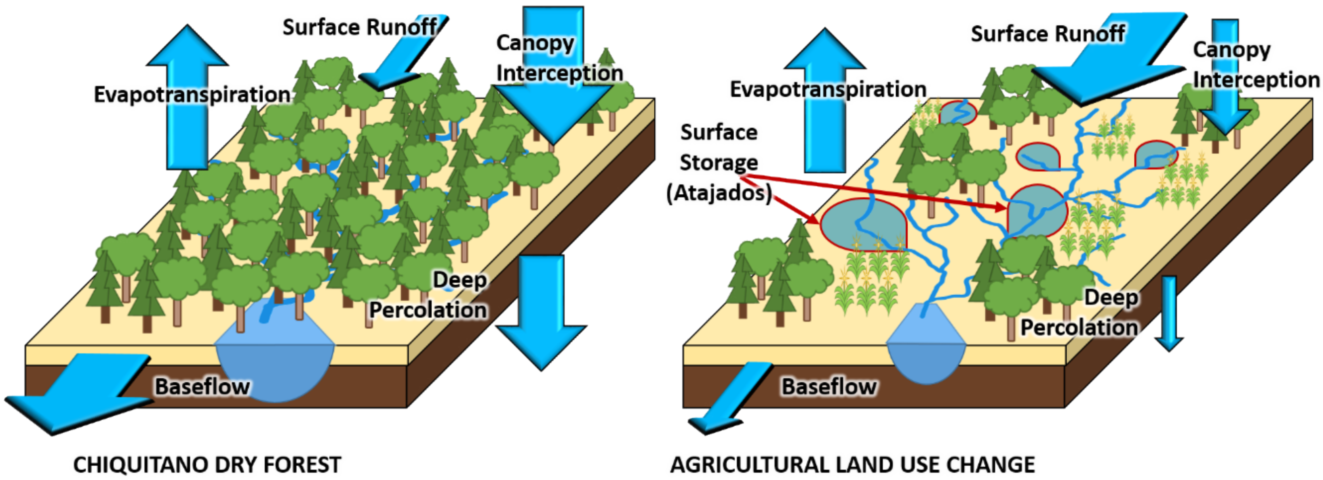
The role of atajados and groundwater extraction at the local and regional scale

As groundwater exploitation expands with little universal understanding of groundwater tables and their historical levels, extraction from interconnected surface and groundwater systems could threaten downstream users and ecosystems. Similarly, changes in surface water storage with the rapid construction of atajados, primarily for cattle watering, could change the natural hydrology of streams and downstream tributaries (Figure 5).

Specifically, surface water storage generally does not infiltrate at a high rate, as it is designed to maintain water levels over time. At the same time, natural lakes and ponds can allow for the encroachment of riparian forest species that allow for deep percolation of water. However, most artificial surface storage is cleaned and kept clear of trees and shrubs. Similarly, the presence of cattle and continuous agricultural clearing reduces the number of tall tree species that intercept precipitation and slow surface runoff. Finally, artificial surface storage keeps water from entering or moving downstream in surface water courses, which helps to slow river flow in the wet season, aiding in flood control, but also creates excessively low baseflows in the dry season. Each of these factors can affect the natural groundwater levels and streamflows – and in turn the people and ecosystems that rely on them – in ways we have yet to understand.

Similar development in California's northern forests, which has been studied more extensively, has led to relatively unregulated, rapidly expanding use of water diversions into unpermitted surface storage. Regulators there have seen marked reductions in streamflow during dry season periods that are critical to native fish and other riparian species in the affected California catchments – which may inform our understanding of how water diversion will affect Bolivia. Such decentralized surface storage can pose significant consequences to ecosystems and downstream water users.

Figure 5. Conceptual model showing the effects of agricultural land use change and the development of decentralized surface water storage on the hydrologic water balance. Agricultural land-clearing and the use of atajados tend to reduce deep percolation and baseflow, while increasing surface runoff, affecting downstream water users and ecosystems.



Future work

Identifying and characterizing the thousands of irrigation and domestic ponds being developed in the region is a difficult task. Planners in the region should continue and expand the use of survey and remote sensing methods to improve the accuracy of decentralized regional water storage estimates and better understand the effects of such storage on forest and regional hydrology. More importantly, municipal and departmental authorities do not currently regulate groundwater use. Local governments could benefit from more knowledge about the current and potential impacts of surface water diversions, particularly the role of atajados, and increasing groundwater extraction to better inform such legislation.

By developing teams with local government and researchers, planners can further develop hydrologic models for the Chiquitania region, focusing on the larger department of Santa Cruz. This modelling will require accurate accounting of water infrastructure, and land use and land cover change, which can be achieved through methods such as remote sensing or drone capture. With more detailed data, researchers will be able to leverage machine-learning tools to characterize the seasonal presence of surface waterwater sources and therefore diversions from streams and rivers in a landscape of changing land uses.

References

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