THE DESERTIFICATION OF LAKE POOPÓ:
AN IMPACT ASSESSMENT OF EL NIÑO AND MINING

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1. INTRODUCTION

Climate variability and potentially change has severely impacted Bolivia and Latin America in recent decades. El Niño, a warming of sea-surface temperatures (SST) above average in the eastern Pacific causing weather perturbations across the globe, has resulted in severe droughts in the already naturally-arid Bolivian Altiplano. In addition, mining activity in the region has historically had significant impacts on the catchment. In January 2016, Lake Poopó was officially declared desertified by the Bolivian government.

Figure 1: Study area (Abarca-Del-Rio et al., 2012). The Lake Titicaca – Desaguadero River – Lake Poopó – Salar de Coipasa (TDPS) catchment is delineated with a dashed red line. The catchment has a total area of 144,000 km². For modelling purposes, this was divided into 100 x 100 m grid cells.

2. MULTI-SCENARIO IMPACT ASSESSMENT

There is a need to investigate the respective impacts of mining and El Niño on water quantity in the lake as well as assess its recovery prospects. In light of this, several hydroclimatic scenarios will be simulated:

- Mining water withdrawal levels combined with a representative El Niño drought event;
- Negligible mining water withdrawal levels combined with a representative El Niño drought event;
- Mining water withdrawal levels associated with long-term climatic trends.

3. METHODOLOGY

GRASS, a Geographical Information System (GIS) software, is used to establish a water balance model for the data-scarce TDPS system. The 1998 El Niño event, with a peak warming of SST of approximately 2.3˚C above average, is considered a valid representation of the ongoing event. Long-term, historical climatic trends are taken as monthly averages between 1970 and 2010.

Mining water withdrawals for copper, lead, zinc and gold production are obtained from the estimates developed by Norgate & Lovel (2004) for each step s of a process per tonne of metal outputted whereas tin and silver are calculated via direct interpolation from available data:

$$W_m = \sum_{c=1}^{c=n} X_c \sum_{s=1}^{s=p} W_s \qquad (1)$$

The Desaguadero River discharge at the entrance of Lake Poopó was recorded along with average potential evapotranspiration E and rainfall P values over the lake. Lake Poopó is an endorheic lake, i.e. it has not output of water other than from direct evapotranspiration. The following catchment water balance equation for the lake is used in order to determine the change in storage:

$$\frac{\partial h}{\partial t} = \frac{Q_{desaguadero} + Q_{regional}}{A_{lake}} + P - E \qquad (2)$$

The following depth-surface area A_{lake} relationship was developed for the lake by Zolá & Bengtsson (2007a):

$$A_{lake} = A_{base} + A_0 \left(\frac{h}{h_0}\right)^{\frac{2}{p}} \qquad (3)$$

A_{base} is the deep bottom floor area, assumed immediately immersed with an infinitesimally small input of water. A_0 and h_0 are optimisation parameters and p is a shape factor.

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Dr. Wouter Buytaert, for his priceless help and guidance throughout this research project.

4. RESULTS

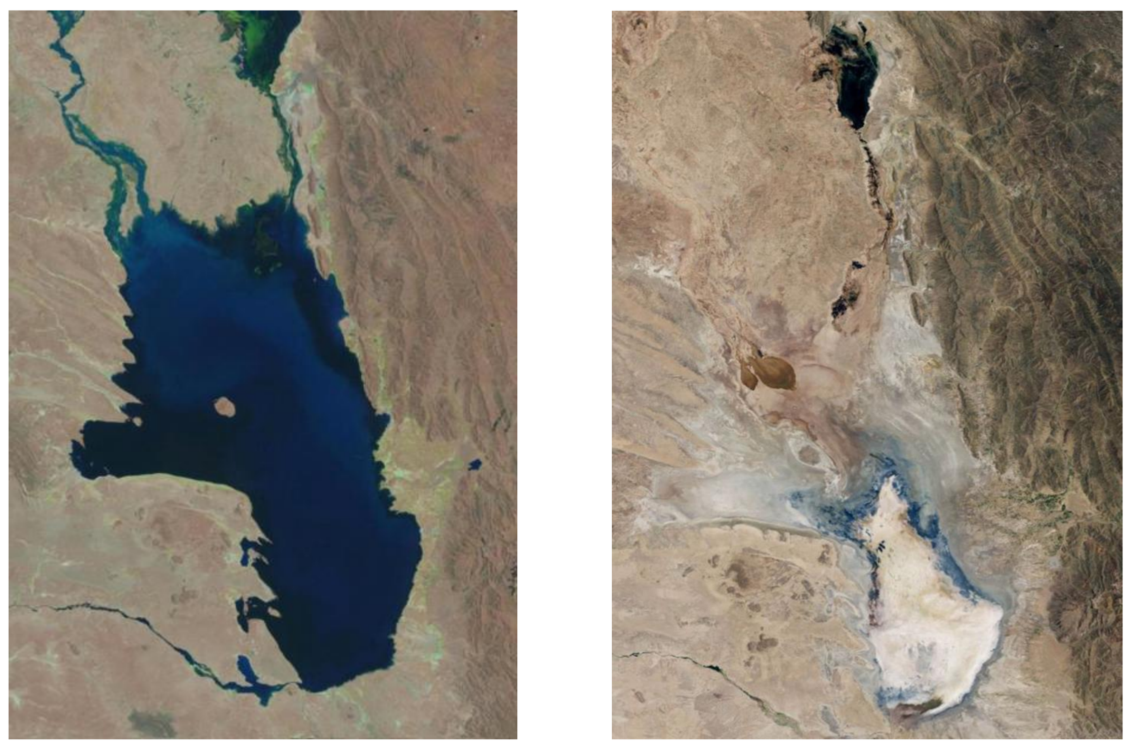
IMPACT OF MINING

Mine m	Ores mined c	Annual metal production capacity X (t/year)	Monthly total water withdrawals W (m³/month)
Bolivar	Lead-Zinc-Silver	15,000 + NA + NA	10,625.00
Coro Coro	Copper	3,600	6,900.00
Huanuni	Tin	10,000	114,697.22
Kori Chaca	Gold	4.1	43,064.86
Kori Kollo	Gold		43,064.86
Poopó	Lead	NA	NA
Tacaza	Copper	3,500	6,708.33
El Cofre	Silver-Zinc-Gold-Lead	41.11 + 1,664 + 0.511 + 2,475 respectively	20,236.68
La Rescatada	Gold	3	63,021.75
San Rafael	Tin	30,000	344,091.67

NA: Not available

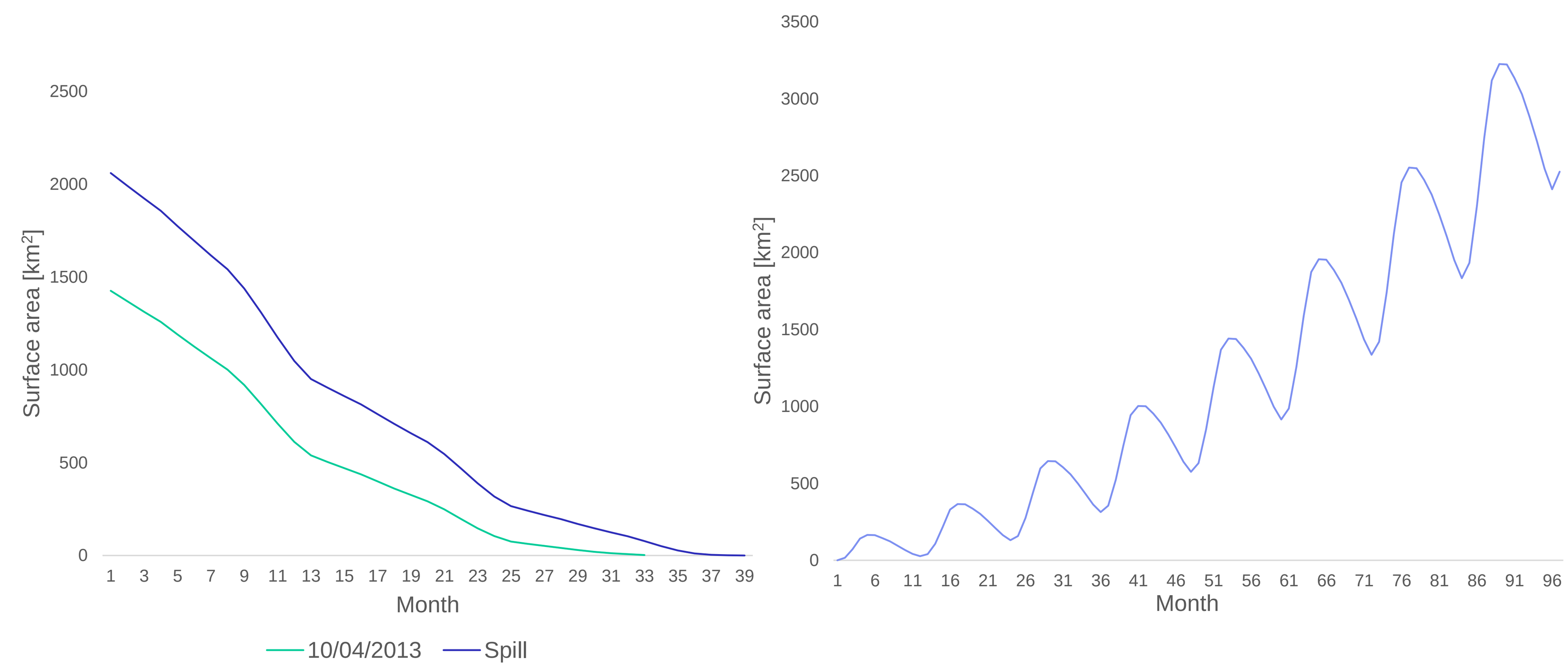
Table 1: Monthly water withdrawals of mines in TDPS catchment. A comparison of total average monthly discharge entering Lake Poopó from the Desaguadero River shows a **reduction of less than only 1%** with mining withdrawals considered. Total water withdrawals account for only 0.2 to 0.4% of total yearly discharge into the lake. All other artificial water withdrawals are ignored here.

IMPACT OF EL NIÑO



(a) 11/10/1986 (b) 15/01/2016

Figure 2: Satellite images of Lake Poopó at spill level and fully dried out (NASA Earth Observatory, 2016).



(a) 1998 El Niño (b) Recovery projections under historical climatic trends

Figure 3: Monthly variation in surface area of Lake Poopó. Under a 1998-equivalent El Niño with all artificial water withdrawals (agriculture, domestic, industrial…) now included, the lake would **dry out in 32 months** with its **starting** point being the observed surface area on **10/04/2013** and similarly **38 months** starting from its **spill** level at a rate of 0.76 m per 12 months. Under 1970-2010 average weather, the lake would **reach** its **10/04/2013 level** in **52 months** and its **spill** level in **74 months**, at a rate of 0.32 m per 12 months. The bottom floor area of 380 km² was not considered for clarity.

5. CONCLUSIONS & FURTHER WORK

- Mining water withdrawals do not appear to impact water quantity in Lake Poopó;
- El Niño, coupled with total artificial water withdrawals, could have caused the lake to dry out.
- Better data availability is needed to be able to conduct further investigation and better inform water management policies in the TDPS catchment.

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