Measuring Surface Extent of High-Elevation Tropical Wetlands to Estimate CO_2 Fluxes

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Introduction

- Wetlands play an active role in the carbon cycle and emit significant quantities of greenhouse gases (GHGs) such as methane (CH_4) and carbon dioxide (CO_2) to the atmosphere (1).
- Wetlands are currently estimated to cover 12.1 million km² of Earth's surface. On a global scale they are estimated to have a CO_2 flux of 0.439–0.683 Pg C yr^{-1}, these contributions generate a positive feedback to climate change. However, they are still not included in Earth system models (2) (3).
- So far, upscaling estimates for carbon budgets exclude very small ponds, less than 0.001 km² in surface area, because it is particularly hard to detect them on maps or satellite images (3).
- On this study, we developed a method to measure the surface extent of wetlands in the paramo, a high-elevation tropical ecosystem of the Andes, to estimate their CO_2 flux .

Methods

SITE

- Research for this project is conducted in the tropical páramo, a high elevation ecosystem of the northern Andes Mountains. This ecoregion is found between tree line and the lowest extent of permanent snow in altitudes from approximately 3500 m to 5000 m.
- Twelve wetlands located within Cayambe Coca National Park, Ecuador were selected to represent a range of landscape positions and surface water extents.
- The elevation of the wetlands ranged between 4098 m and 4109 m, and the surface extent between 21 m² and 5385 m².

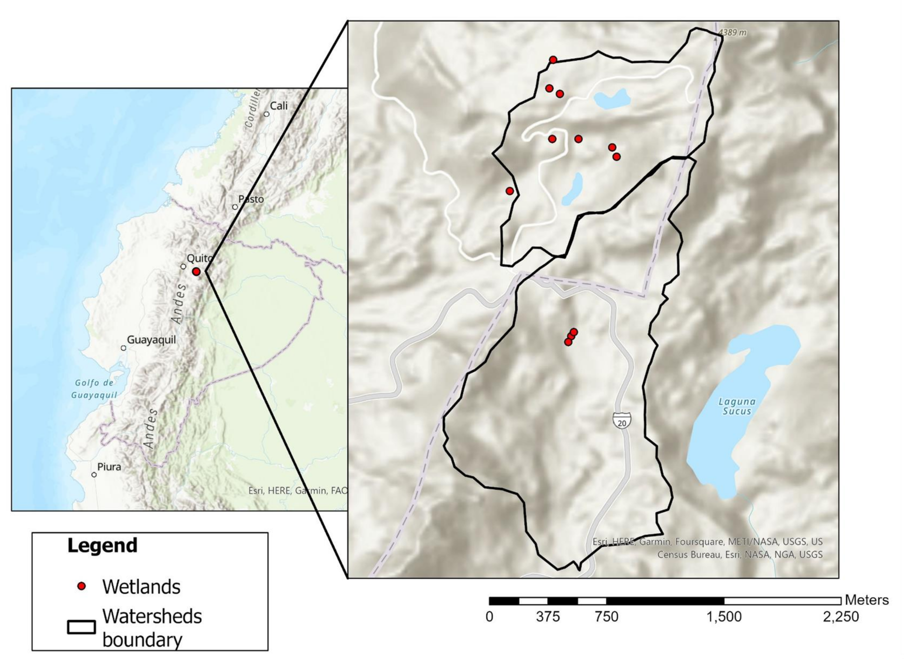

Figure 1. Location of the wetlands within the Gavilan (top) and Colmillo (bottom) watersheds.

WATER LEVEL AND SURFACE EXTENT

- Water level loggers were installed at each wetland collecting data every 15 minutes
- A lightweight quadcopter drone (Anafi; Parrot SA, Paris, France) was flown at each wetland using missions planned in Pix4Dcapture software (Pix4D SA, Prily, Switzerland).
- The drone was flown at least four times between June 2022 and January 2023. This time period includes both wet and dry seasons at the field site.
- Photos were stitched together using Pix4Dmapper. The resulting raster allowed manual measurements of surface area extent in ArcGIS Pro

Delineating Wetlands with ArcGIS Pro

Import raster
- Import the wetland raster created previously in Pix4Dmapper

Create new feature class
- In the *Catalog Pane* create a new *Feature Class* in the project's geodatabase

Trace wetland
- On the *Edit* window, select *Create* and choose polygon. Trace the edge of the wetland and *Save*. The area is found on the attribute table of the newly created polygon.

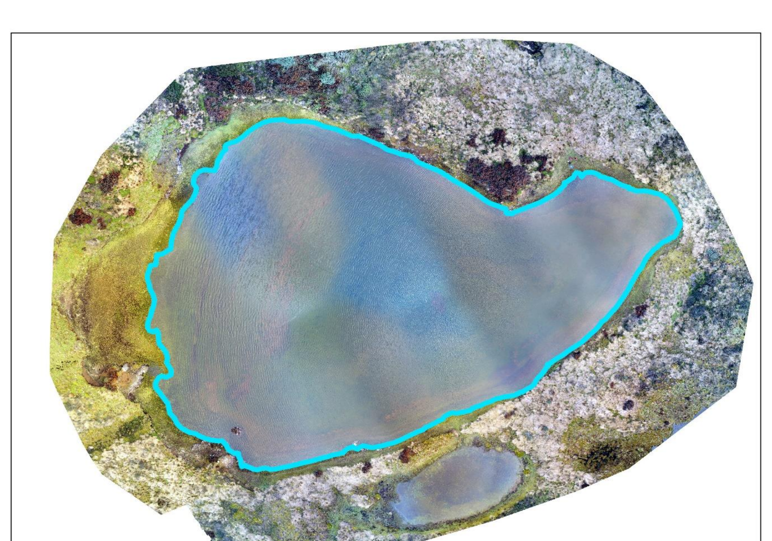

Figure 2. Result from delineation process in ArcGIS Pro.

Methods Continued

PREDICTING WATER SURFACE EXTENT

- The continuous water level data collected and its relationship to surface extent allowed us to do a regression line to predict surface extent of the wetlands during the days and times not captured by the drone
- Wetlands 1 and 3 did not show any significant surface extent change over time. Instead of a regression line equation we used their average surface extent

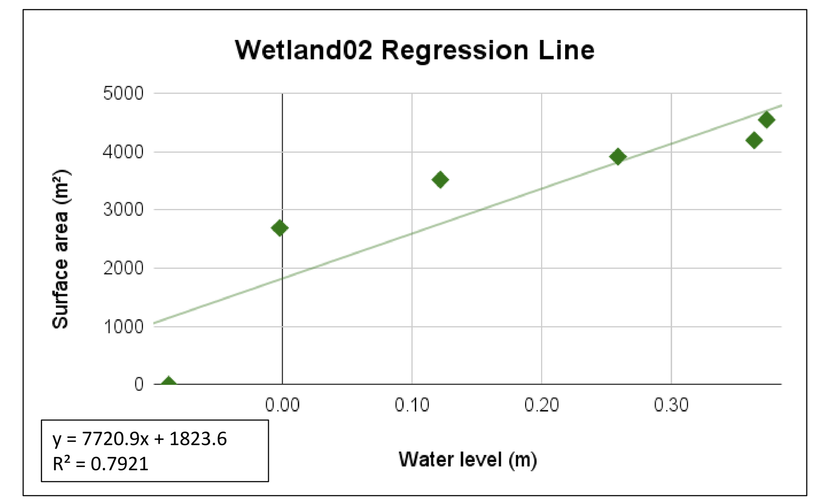

Figure 3. Linear regression model using the relationship between water level and surface extent.

GAS SAMPLING

- Gas sampling took place at each wetland three times during the wet season between June and July 2022. pCO_2 and pCH_4, and CO_2 flux was measured at three locations along a transect through the center of the wetlands. A CO_2 sensor was programmed to collect data at 1-sec intervals. At each sample point, sensors were allowed to equilibrate with the surrounding water for at least 15 minutes.

PRECIPITATION

- Precipitation occurs almost daily, with an average of 1066 to 1401 mm year^{-1} from 2007 to 2013 (4). Precipitation data is obtained from Fondo de Agua para Quito (FONAG) Virgen Papallacta Station less than 2 km from the furthest sampling site.

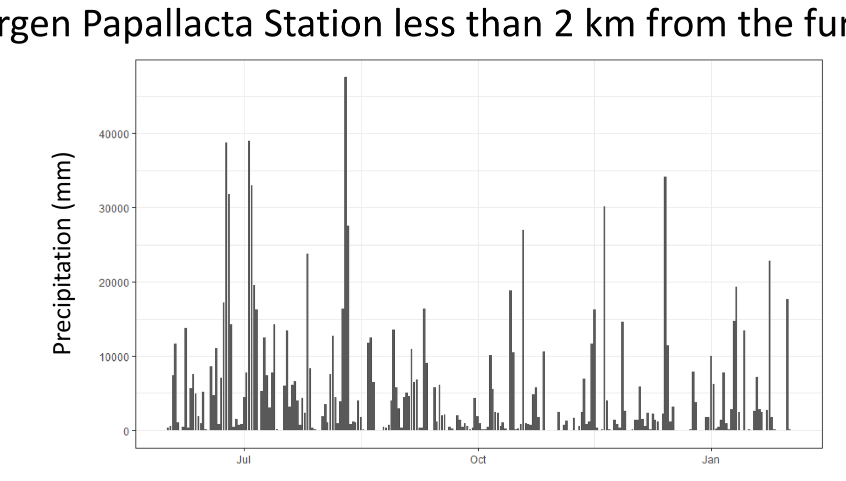

Figure 4. Daily precipitation data obtained from Virgen Papallacta weather station from June 2022 to March 2023.

Water Level and Surface Extent Results

Wetland	Equation	R^2
1	$y = 5328.37$	N/A
2	$y = 7720.9x + 1823.6$	0.7921
3	$y = 840.90$	N/A
4	$y = 1673.2x - 197.93$	0.9408
5	$y = 546.03\ln(x) + 999.47$	0.7293
6	$y = 150.45\ln(x) + 434.68$	0.8375
7	$y = 637.43\ln(x) + 1225.1$	0.9673
8	$y = 724.3x - 133.37$	0.8800
9	$y = 73.721\ln(x) + 60.975$	0.9653
10	$y = 41.184\ln(x) + 76.444$	0.5573
11	$y = 41.184\ln(x) + 76.444$	0.7139

Table 1. Equation from linear regression of water level and surface extent relationship.

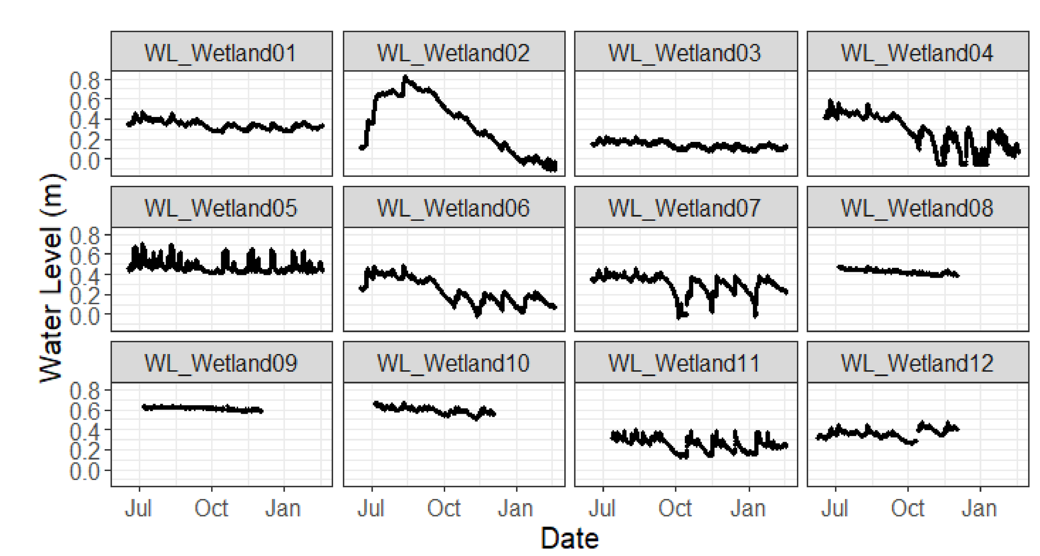

Figure 5. Water level of all wetlands in the study from June 2022 to March 2023.

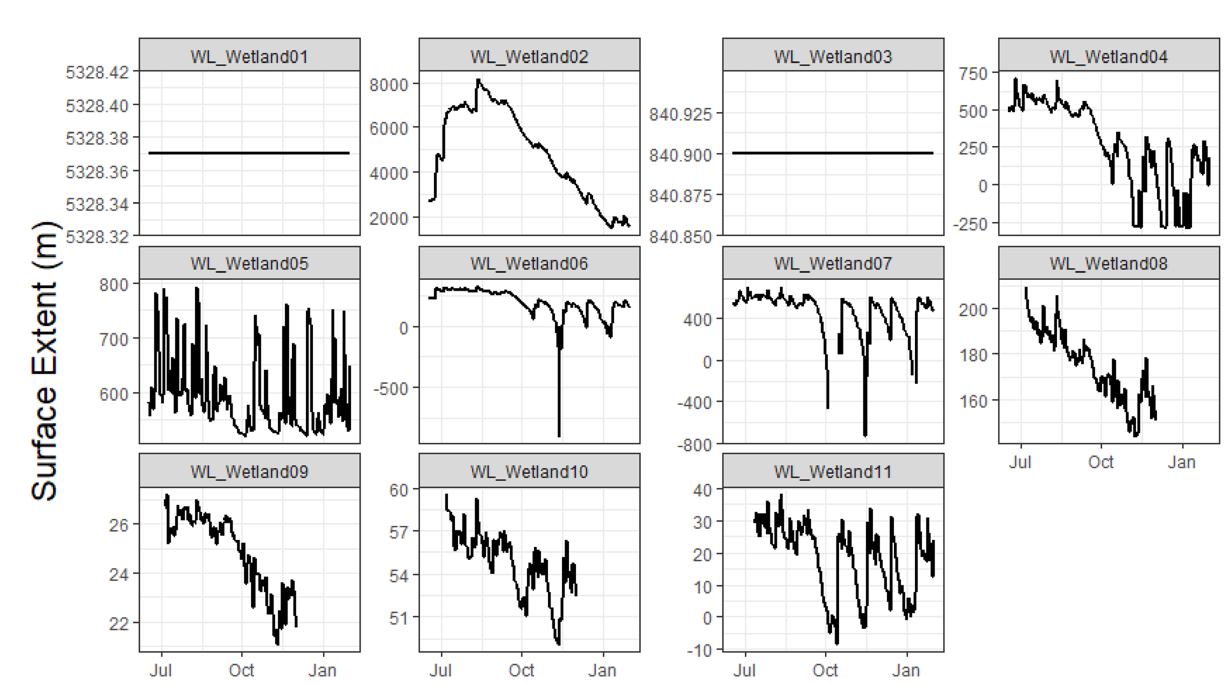

Figure 6. Surface extent predicted by water level values using the linear regression equation from Table 1.

Carbon Dioxide (CO_2) Flux Results

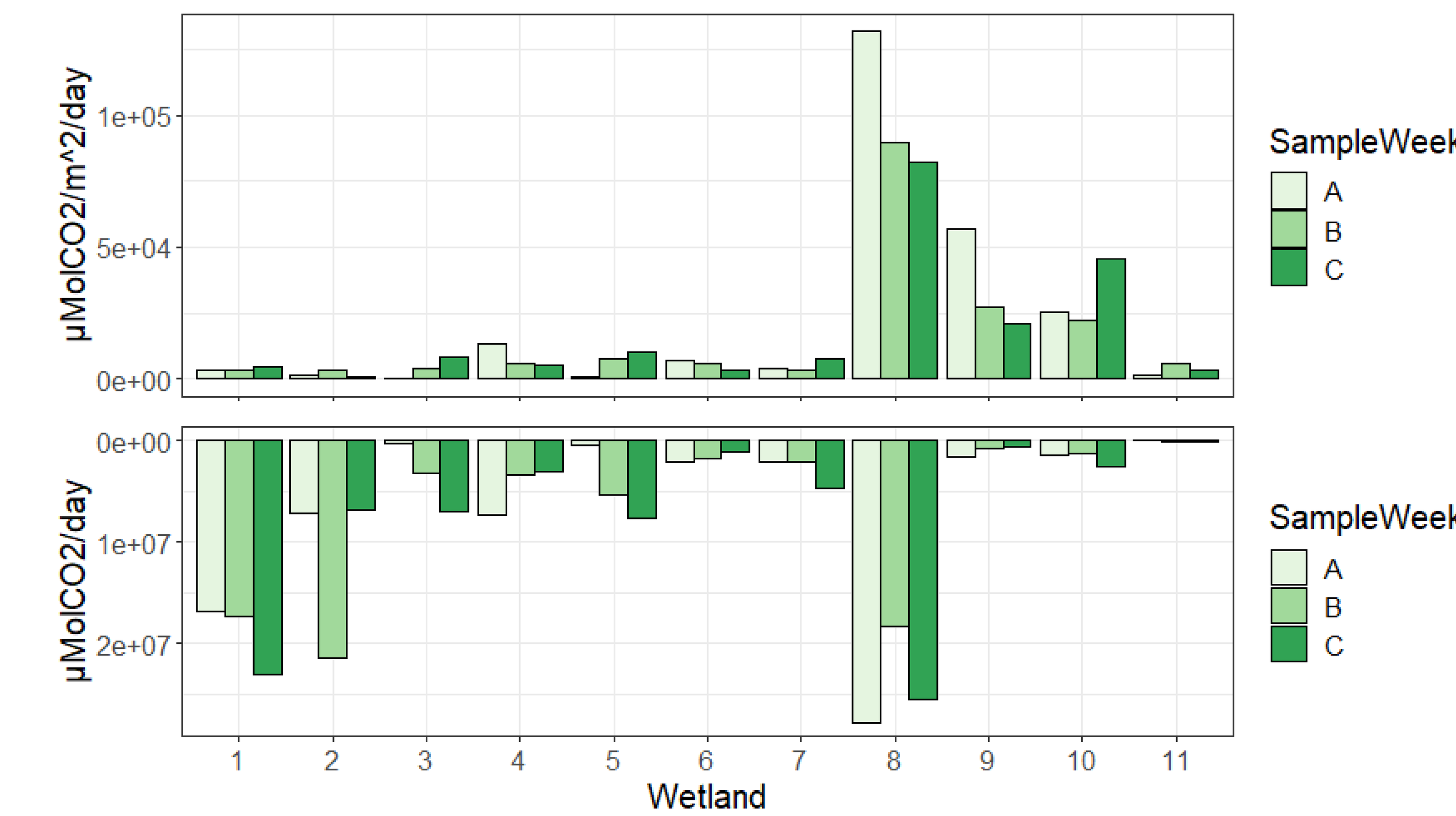

Figure 7. Estimated average daily flux by sample week by wetland (top). Estimated average daily flux by sample week by wetland taking surface extent into consideration (bottom).

Rank	Wetland #	Ave Flux (ɥMol/m²/day)	Rank	Wetland #	Ave Flux (ɥMol/day)
1	Wetland08	101,304	1	Wetland08	23,904,732
2	Wetland09	34,986	2	Wetland01	19,096,885
3	Wetland10	31,131	3	Wetland02	11,804,413
4	Wetland04	8,243	4	Wetland04	4,588,451
5	Wetland05	6,218	5	Wetland05	4,499,905
6	Wetland06	5,496	6	Wetland03	3,518,535
7	Wetland07	5,024	7	Wetland07	3,013,954
8	Wetland03	4,184	8	Wetland10	1,794,554
9	Wetland01	3,584	9	Wetland06	1,610,731
10	Wetland11	3,193	10	Wetland09	935,598
11	Wetland02	1,713	11	Wetland11	99,283

Table 2. Comparison of ranking order of average flux with (ɥMol/day) and without (ɥMol/m²/day) taking surface extent into account.

Conclusions

- All the wetlands in this study were found to emit CO_2 into the atmosphere.
- Developing a method to measure wetland's surface extent is needed to include small wetlands and better estimate carbon budgets in Earth system models.
- When taking surface extent into consideration, the flux values change relative to their surface extent. We observe an increase in CO_2 flux for larger wetlands and relative a decrease for smaller wetlands.
- In this study the CO_2 flux ranged from 1,713 to 101,304 ɥMolCO₂ /m²/day and we estimated the daily flux to range from 99,283 to 23,904,732 ɥMolCO₂/day.

Acknowledgements

This work was supported by the National Science Foundation (EAR-1847331), Society for Wetland Scientists and Geological Society of America. We would like to thank the staff at the University of San Francisco Quito (USFQ) for logistical support as well as the communities of Cumbayá and Quito, Ecuador. We thank the Ministry of the Environment of Ecuador (research permit 014-018-IC-FLO- DPAN/MA) and the National System of Protected Areas of Ecuador for site access.

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