water

Supplementary Material

Long-Term Annual Surface Water Change in the Brazilian Amazon Biome: Potential Links with Deforestation, Infrastructure Development and Climate Change

Section 1: Google Earth Engine code for visualization and download interface.

Section 2: Statistical analysis of deforestation and surface water dynamics at watershed scale.

Section 3: Global Surface Water (GSW) analysis.

Section 1:

Google Earth Engine code for visualization and download interface of the following products:

- Annual surface water detection with SWSC from 1985–2017
- Frequency map showing the number of water detections per pixel within the time series
- Annual surface water transition (gain/loss) areas from 1985–2017
- Annual water body classifications from 2000–2017

Instructions

1. Select a year on the time line on the bottom of the app interface.
2. Click on the button "Show" beneath the product names to show them on the map.
3. Define a rectangular limit to export the chosen products within the rectangle as GeoTIFF data on your Google Drive repository by clicking on the map at the chosen location of the rectangle's diagonal corners. The area to export is limited to avoid overloading the export task.

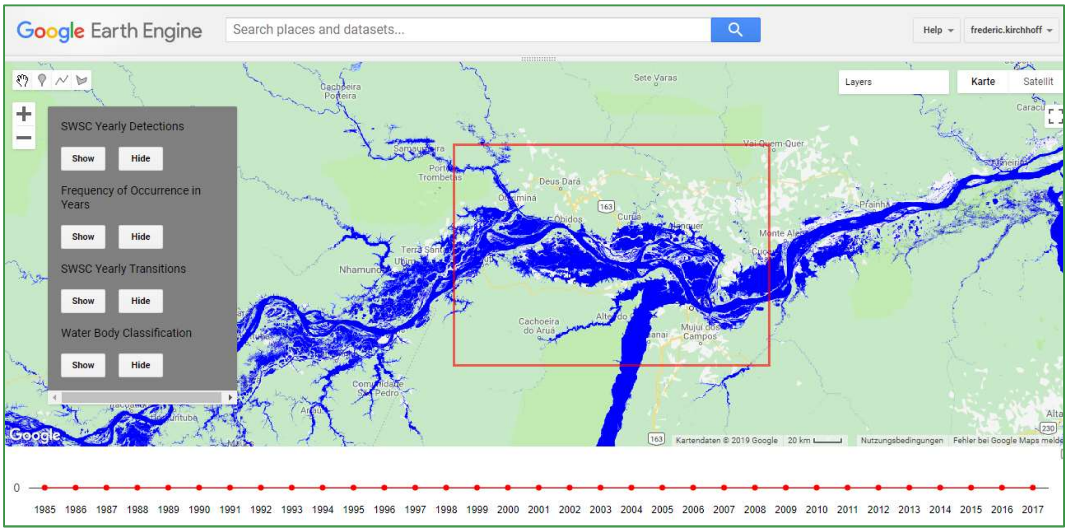


Figure S1. Visualization and download interface on Google Earth Engine. Google Earth Engine Link to run the app above (copy and paste it to Code Editor and run it): https://code.earthengine.google.com/3a4e78799b0726409de84dc80b572bd8.

Section 2:

Statistical analysis of deforestation and surface water dynamics at watershed scale. Supporting table to the statistical analysis is in the Google Drive link below (copy and paste it to your web browser):
https://docs.google.com/spreadsheets/d/1GcUIJxHImUalLf2_BjlQbFFEuiTiK3p7_lkgAqX8fIM/edit?usp=sharing

We evaluated the effect of deforestation and forest cover in surface water area was evaluated using a linear model of the form:

$$log(|y^{*}|) = log(d + 1) + log(w + 1) + log(f + 1) + e_b + e$$

Where $|y^{*}|$ is surface water change per watershed, d (deforestation), w (surface water) and f (forest) are control variable per watershed. The deforestation data source is from Prodes ((available here: http://www.obt.inpe.br/prodes/dashboard/prodes-rates.html), and the forest cover from MapBiomas (see mapbiomas.org for data access).

We tested two models with Equation 1: one with only the watersheds that gained surface water; and another with only the watersheds that lost surface water between 1985 and 2017. The tables below show the results for the two models.

Table S1. Coefficients for Model 1 - watersheds that have annually gained surface water.

	Estimate	Std. Error
(Intercept)	−0.3245977	0.0409905
I(log(deforestation + 1))	0.0579216	0.0078613
I(log(water + 1))	0.5530253	0.0088173
I(log(forest + 1))	−0.0336622	0.0085747

Table S2. Coefficients for Model 1 - watersheds that have annually lost surface water.

	Estimate	Std. Error
(Intercept)	−0.5028968	0.0422073
I(log(deforestation + 1))	−0.0255440	0.0083501
I(log(water + 1))	0.3759439	0.0089464
I(log(forest + 1))	0.1037710	0.0086562

The models require normally distributed, uncorrelated and homoscedastic residuals and no multicolinearity. We overcame auto-correlation of water surface change for this analysis, using model residuals in the statistical test described above. We observed a low correlation of deforestation against the other variables as showed in the correlation matrix (Figure S2). Because the water surface area change is proportional to the area, the residual variance is proportional to the $log(w + 1)$. A test model including w in the linear scale did not change the results. Therefore, annual deforestation seems to be slightly associated to increasing water surface area in watersheds that were more deforested during 1985 and 2017, while the loss of surface water seems to be strongly related to higher forest cover.

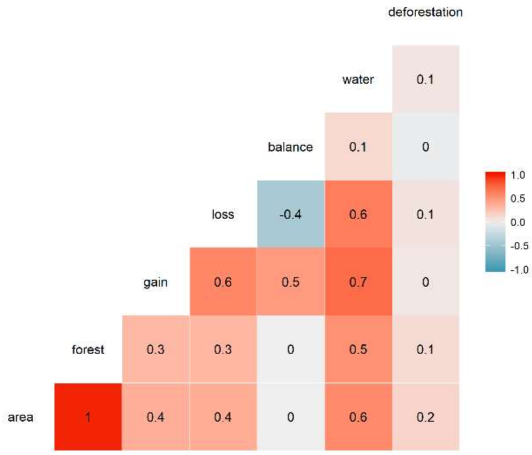


Figure S2. Correlation matrix of all variables in the models described above.

Section 3: Global Surface Water (GSW) analysis

We have estimated monthly surface water extent for GSW. The table with these estimates is available in the Google Drive link below:
https://docs.google.com/spreadsheets/d/1E7AEZe_YiV2QFxPsKDP2468ocI4x4AYMJ6XMkXxuVM4/edit?usp=sharing

The GSW dataset provides monthly global surface water maps during 1984 and 2015. This dataset is available in Google Earth Engine as a collection. We estimated monthly statistics of surface water extent from the GSW dataset. Overall, GSW detected less surface water in Wet months compared to Dry months (Figure S3). This may be associated with high and frequent cloud occurrence during the wet season.

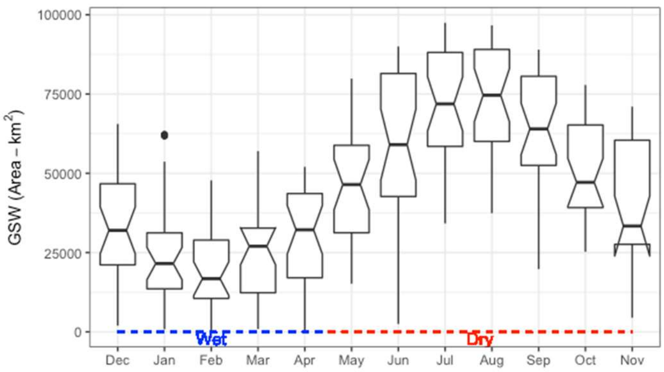
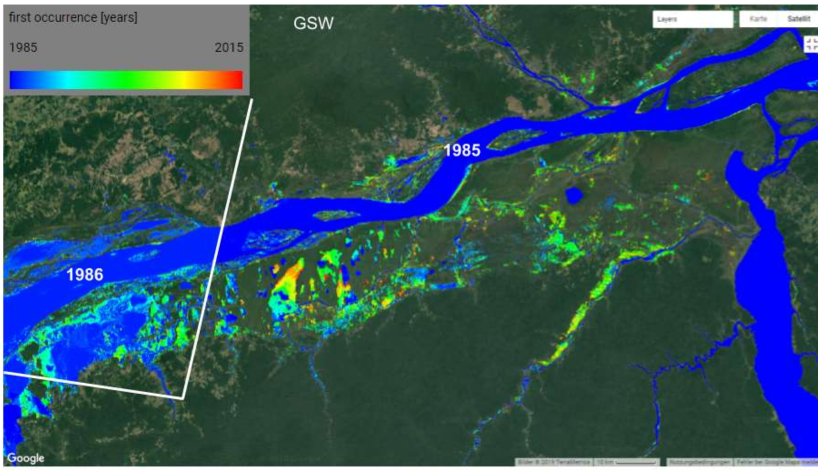
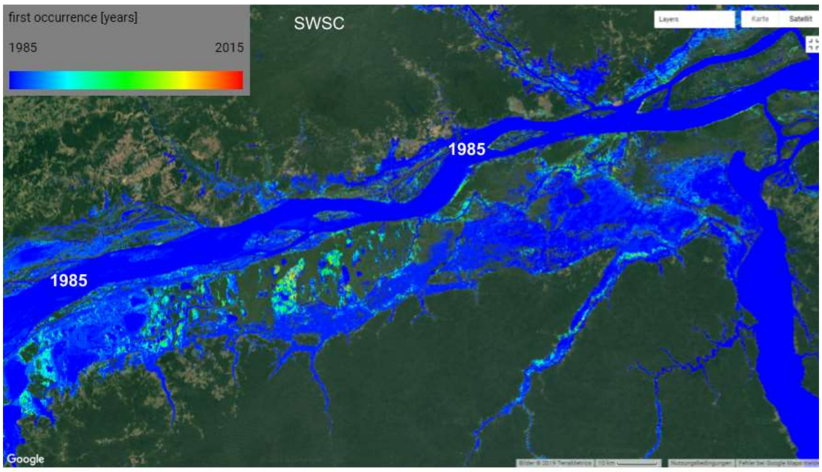


Figure S3. Boxplot of the monthly GSW detection of surface water between 1987 and 2015 showing more surface water detected in Dry months, relative to Wet months.

We also compared the first occurrence of water detection using GSW and the Surface Water Sub-Pixel Classifier (SWSC) (Figure S4). GSW showed late detection (light blue, green and yellow colors) relative to SWSC in flood plains, some large rivers and in small streams (not visible in the scale of Figure S4B).



(**A**)



(B)

Figure S4. First surface water occurrence in the GSW (**A**) and SWSC (**B**) between 1985 and 2015.

Finally, we also evaluated water and land interchange between 1991 and 2015 using GSW dataset for the Dry season (circa 1 June through 31 October; Figure 5S), with the results for SWSC (Figure 6 in the manuscript, between 1991 and 2017). Even though we used 2015 in the GSW, this year showed a reduction in surface water in the SWSC (Figure 4 in the manuscript). Therefore, GSW did not detect the same extent of changes as detected with SWSC in flood plains, wetlands and along small rivers, suggesting that sub-pixel information reveals more surface water information than whole-pixel used in GSW.

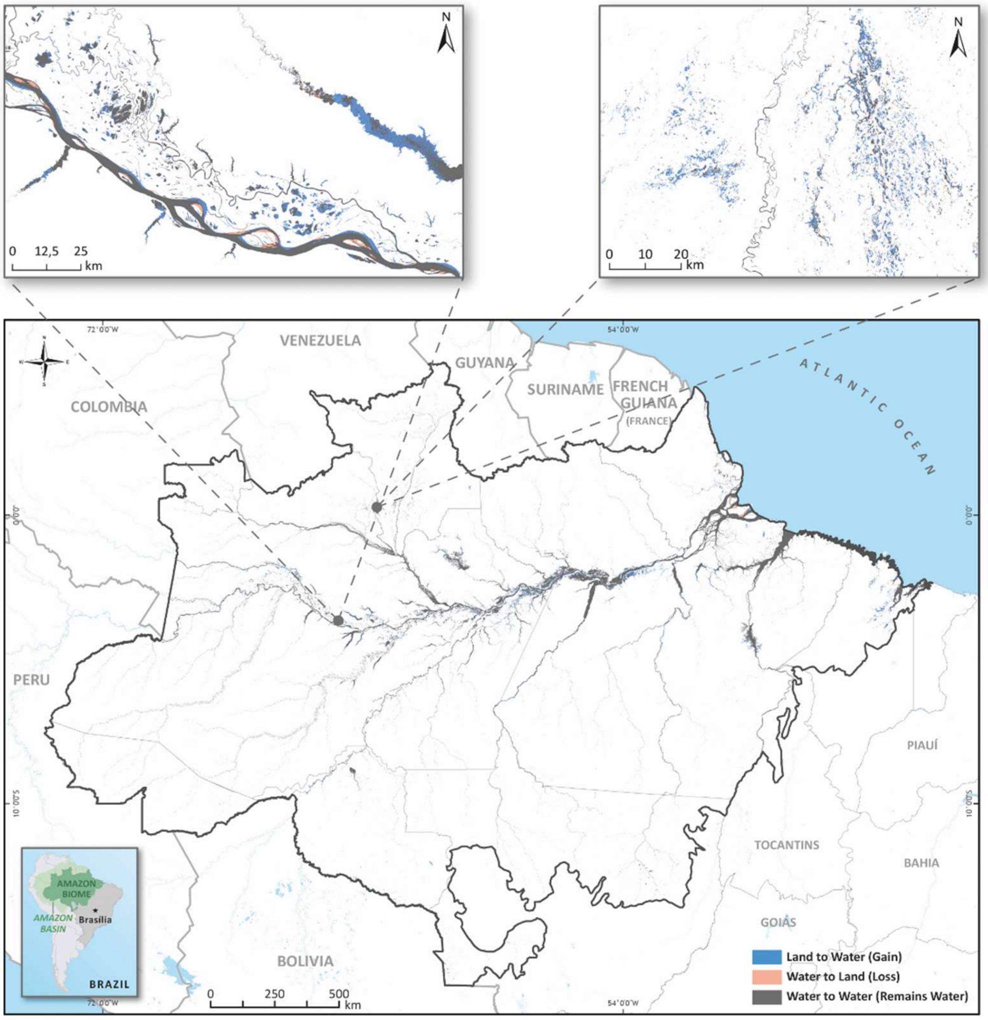


Figure S5. Interchange between water and land detected between 1991 and 2017 obtained with GSW dataset for the Dry season. These years showed the highest and lowest surface water extent, respectively, using SWSC (see Figure 6 in the manuscript for comparison).