remote sensing

MDPI

Article

Chlorophyll Fluorescence Data Reveals Climate-Related Photosynthesis Seasonality in Amazonian Forests:

Supplementary Materials

BFAST Application

The BFAST (Breaks in Additive Season and Trend) algorithm was developed in the R language (http://bfast.R-Forge.R-project.org/). BFAST is based on an additive decomposition model obtained from a time series (Verbesselt et al., 2010), decomposed in the trend, seasonality and remainder components. Decomposition of the time series data from this algorithm can be represented by the following formula:

$$Yt = St + Tt + et_{\mathrm{n}} \quad (1)$$

Where:Yt is the observed data at time t, Tt is the trend component, St is the seasonal component and et_n is the residual component.

BFAST was applied to the ChlF time series (2007-2015). The Figure S1 shows the three components obtained by the BFAST application in a pixel of the ChlF time series, located in 62.5 lon and 4.3 lat.

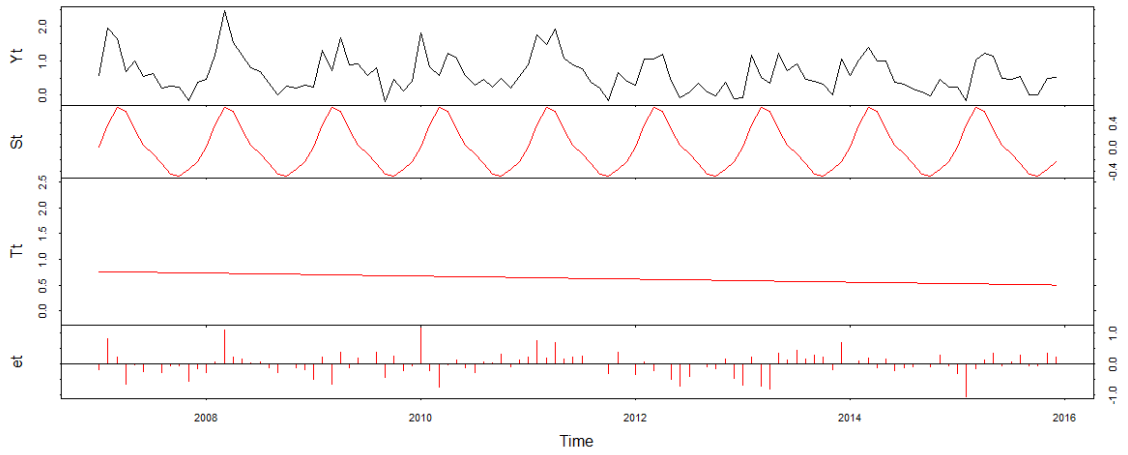

Figure S1. Components obtained by decoupling the ChlF observed data (Yt). Tt represents the trend component, St the seasonal component and et the residual component

Monthly Annual Mean of Climate Variables over the 2007–2015 Period

The Monthly annual mean of radiation and precipitation data was obtained averaging the months over the 2007–2015 period. For example, the January mean was obtained by the next formula:

$$\overline{Jan} = \frac{Jan_{2007} + Jan_{2008} + Jan_{...} + Jan_{2015}}{12} \quad (2)$$

Vegetation Types

We obtained the vegetation types from the Global Land Cover 2000 database (Global Land Cover 2000 database, European Commission, Joint Research Centre, 2003 (http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php). The map showing the vegetation types is showed in the Figure S.6.

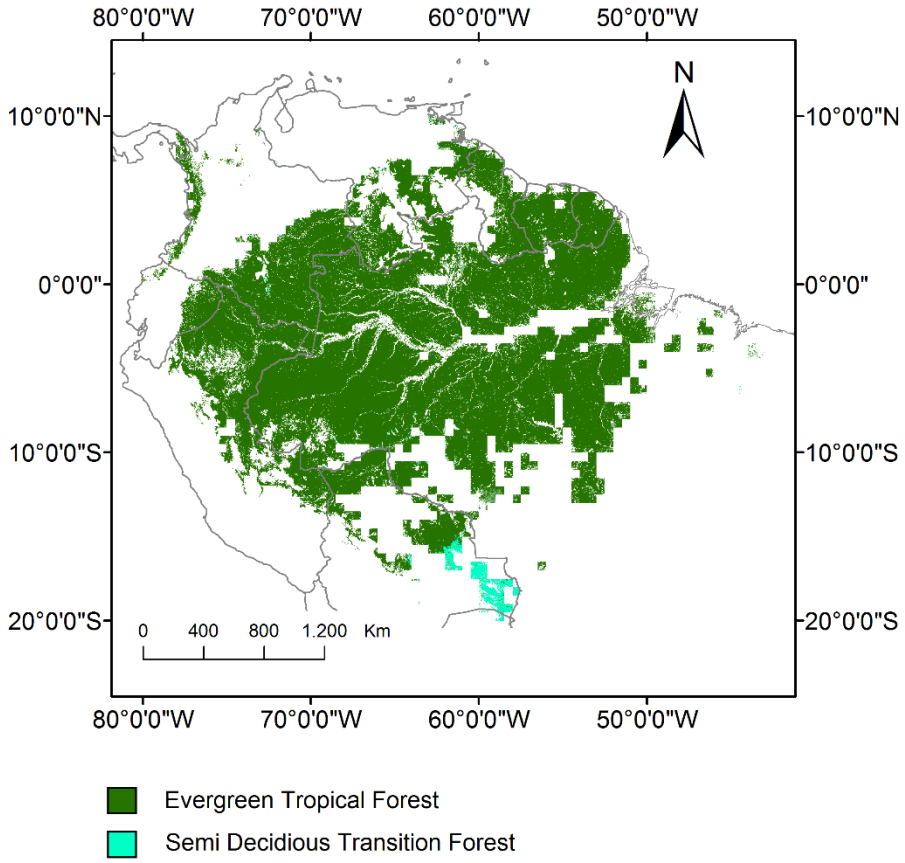

Figure S.2. Dominant vegetation types occurring in the study area.

Mean Annual Precipitation

The Figure S5 shows the mean annual precipitation for the 2007-2015 period obtained from the TRMM resampled data. The INMET ground stations also are showed in this figure.

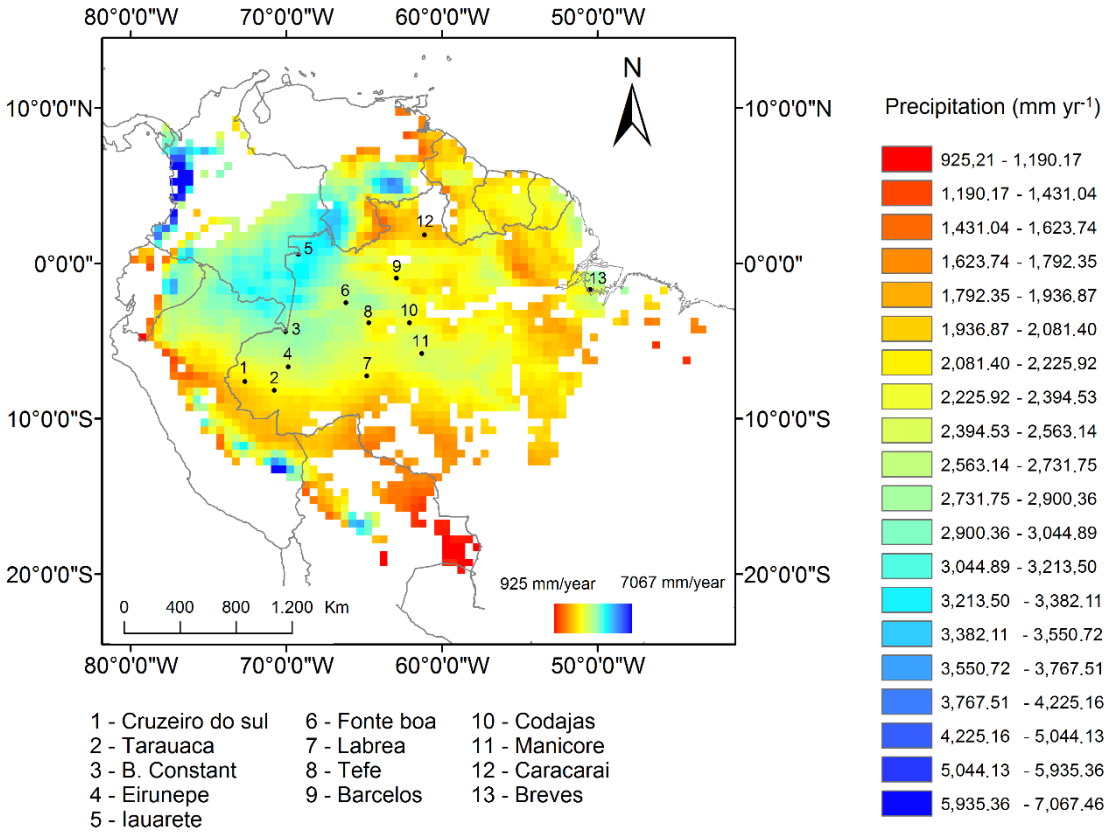

Figure S.3. Mean annual precipitation of the 2007–2015 period obtained from TRMM. The numbers indicate the location of the INMET ground stations.

The TRMM precipitation monthly time series related to a pixel where an INMET ground station are located was obtained. The Caracarai station, for example, has the following coordinates: -61.12 lon and 1.83 lat, so the TRMM precipitation monthly time series related to the pixel located in such coordinates was obtained. Figure S6 shows the ground observed precipitation time series from the Caracarai station and the TRMM precipitation monthly time series related to the pixel located in the station coordinates. The INMET ground stations were obtained accessing < http://www.inmet.gov.br>.

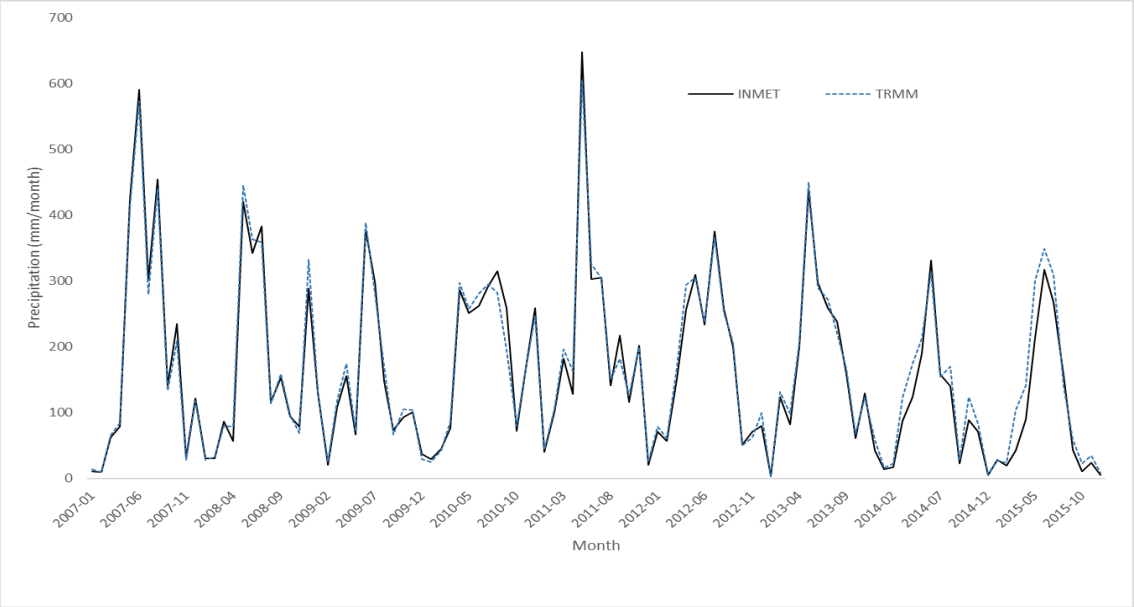

Figure S4. Monthly precipitation values obtained from the Caracarai INMET station and from the TRMM pixel where this station is located.

TRMM precipitation data obtained a mean determination coefficient equals to 0.94 with the ground precipitation observations from the INMET stations (Table S.1) – all greater than 0.825, what indicates that the TRMM data (spatial resolution passed from 0.25° to 0.5°) can reproduce the precipitation in such areas. The TRMM data biased 36.4 mm in relation to the INMET rain gauges, as showed by the averaged Root Mean Square Error in the Table S.1.

Table S.1. Pearson correlation coefficients obtained between the INMET stations and the corresponded pixels in the TRMM time series.

INMET Stations	Lon	Lat	Correlation	RMSE
Barcelos	-62.91	-0.96	0.857	61.97
Benjamin Constant	-70.03	-4.38	0.939	25.78
Breves	-50.48	-1.68	0.970	39.16
Caracarai	-61.12	1.83	0.988	21.01
Codajas	-62.08	-3.83	0.959	33.49
Cruzeiro do Sul	-72.66	-7.6	0.943	30.22
Eirunepe	-69.86	-6.66	0.967	37.18
Fonte Boa	-66.16	-2.53	0.825	66.23
Iauarete	-69.18	0.61	0.906	45.51
Labrea	-64.83	-7.25	0.975	30.30
Manicore	-61.3	-5.81	0.984	25.94
Tarauaca	-70.76	-8.16	0.970	30.23
Tefe	-64.7	-3.83	0.971	26.21
Mean			0.943	36.40

GLDAS shortwave data obtained a mean determination coefficient equals to 0.723 with the ground maximum temperature observations from the INMET stations (Table S.1) – all greater than 0.629, what indicates that the TRMM data (spatial resolution passed from 0.25° to 0.5°) can reproduce the precipitation in such areas. We used only the stations without missing values for the maximum temperature observed.

Table S.2. Pearson correlation coefficients obtained between the INMET stations and the corresponded pixels in the GLDAS time series.

INMET Stations	Lon	Lat	Correlation
Barcelos	-62.91	-0.96	0.724
Caracarai	-61.12	1.83	0.663
Codajas	-62.08	-3.83	0.629
Cruzeiro do Sul	-72.66	-7.6	0.702
Eirunepe	-69.86	-6.66	0.715
Labrea	-64.83	-7.25	0.779
Manicore	-61.3	-5.81	0.810
Tarauaca	-70.76	-8.16	0.774
Tefe	-64.7	-3.83	0.748
Mean			0.723

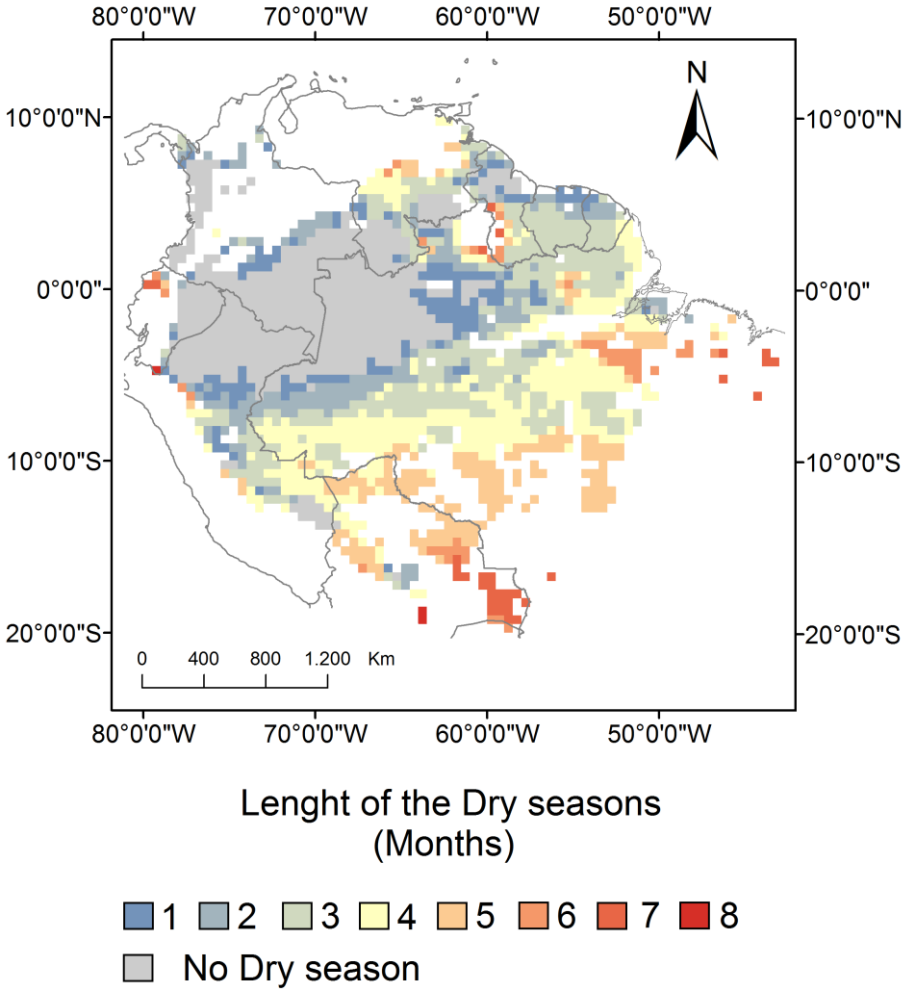

Figure S.5. Length of the dry seasons occurring in the study area.

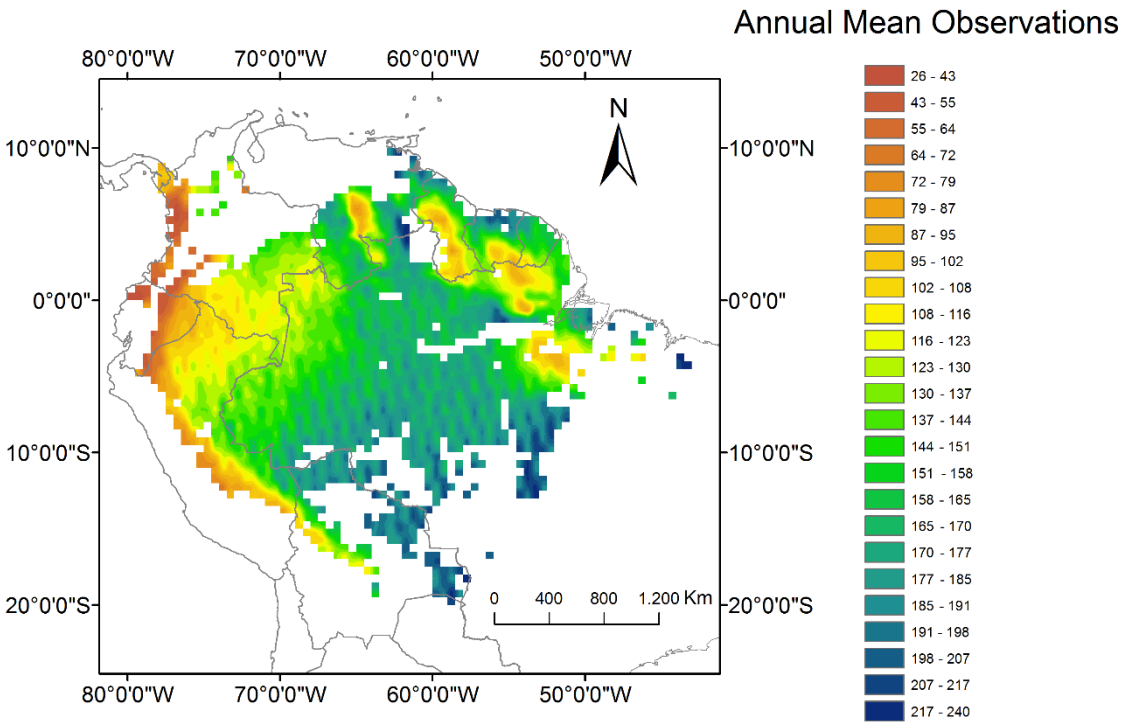

Figure S.6. Mean Annual Count of ChlF observations from the GOME-2 sensor.

Spatial Variation of the Month Lags

In 39.06% of the Amazon forest the model performed well modeling photosynthesis without any time lag in radiation. By applying a one-month lag in radiation, the model got better results in 39.76% of the Amazon forest, while with two and three months lags the model got better results in 18.31% and 2.87% of the Amazon forest, respectively. Even though the areas where the model got better results by applying no lag are distributed over all amazon, they are more concentrated in the southern and northwest amazon (Figure S2). Two-lag areas are located mainly in center of amazon and one-lag are distributed over all amazon, with exception to the southern. Three lag areas occur in the southeast and in some regions in the northern amazon.

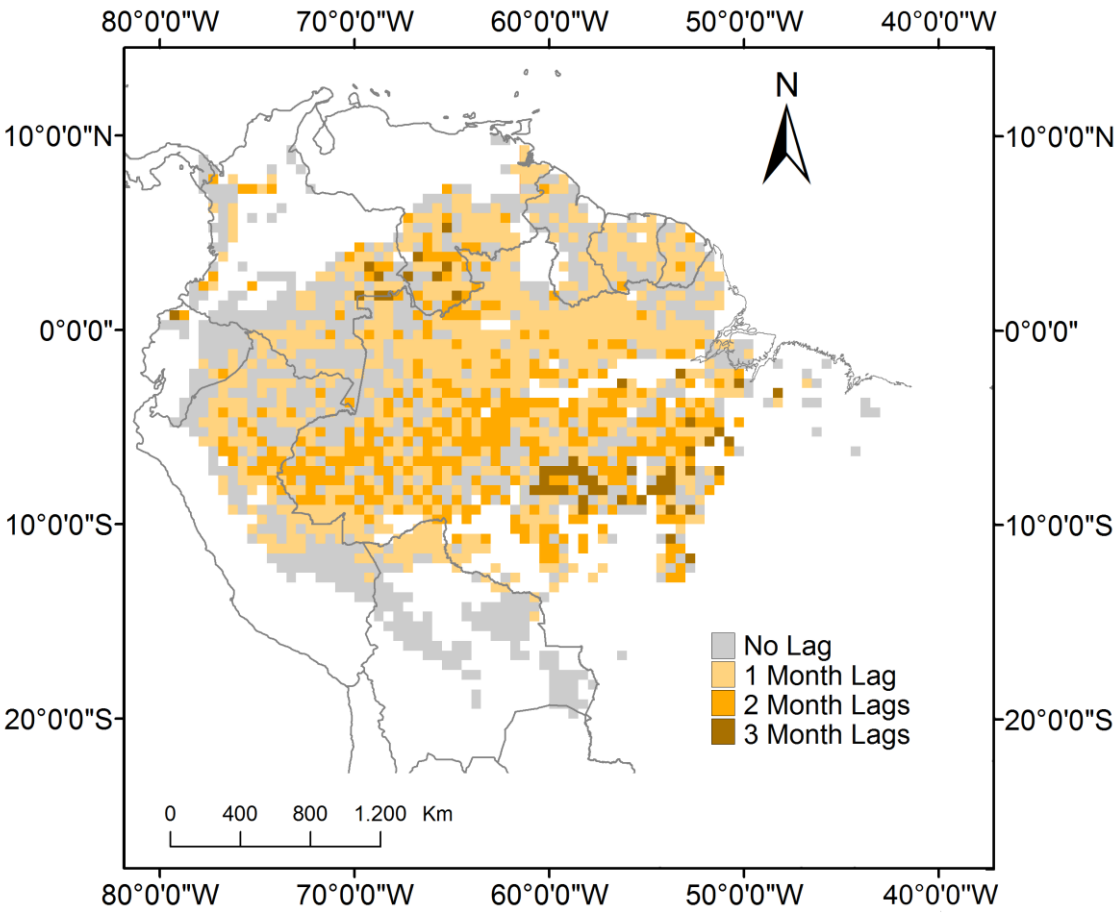

Figure S.7. Best fit in the model by applying one, two, three months lag or no lag in the radiation component.

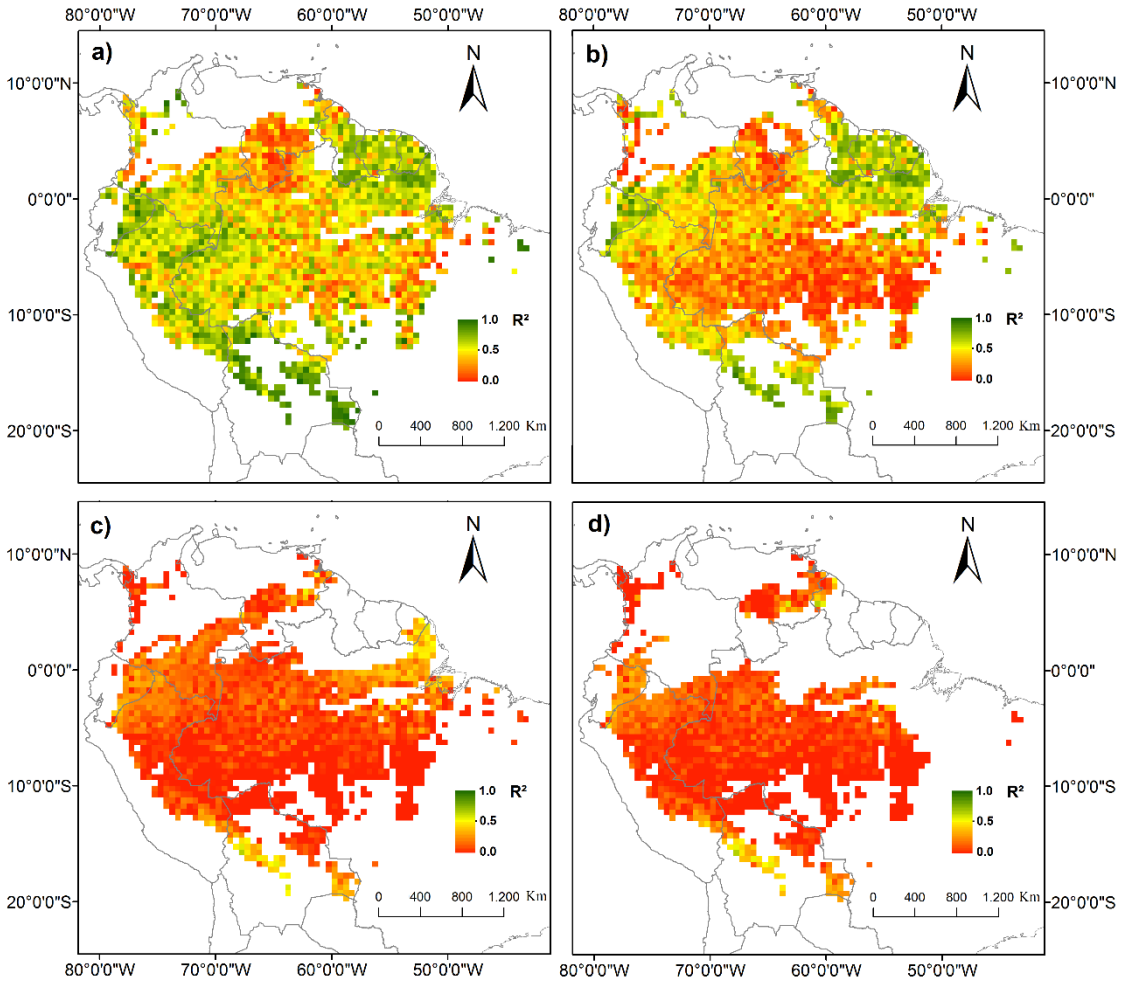

Figure S.8. Coefficient of determination obtained by applying the model with a) Zero, b) One, c) Two and d) Three months lag in precipitation (Pre). Correlations between radiation and precipitation equal to or higher than 0.5 were excluded to avoid artificial correlations between these two variables.