

Neural Network model for classification of net CO₂ fluxes scenarios in Tapajós Forest, in Amazon

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Abstract

The Amazon rainforest has a great influence on the global energy balance and carbon fluxes, responsible for the net removal of approximately 4 million tons of carbon per year, via photosynthetic activity. Climate change and deforestation have impacts on the carbon budget in Amazonia, transforming CO₂ sink areas into sources. Given the complexity of the factors that govern the carbon exchange in the Amazon and its influence on biological processes, the use of Data science strategies can promote a better understanding about the main environmental factors for different scenarios, and also, assist in public policies to mitigate the global warming effects. This study aims to identify the environmental factors that determine the temporal variability of carbon exchanges between the biosphere and the atmosphere in the Tapajós National Forest, in the Amazon, applying Data Science strategies in an integrated set of environmental data from energy and carbon fluxes and remote sensing data. The specific objective is to assess the influence of a selected set of environmental variables on the variability of carbon exchanges, with the use of an artificial neural networks classification model to identify the variables with great impact on source, sink and neutrality scenarios in Tapajós National Forest. Data Science strategies were applied to an integrated dataset of ground-based carbon flux measurements and remote sensing data, considering the period between 2002 and 2006. An artificial neural network (ANN) classification model was developed to identify the environmental variables with great impact on carbon source, sink and neutrality conditions. The average global score of ANN model was 65%. It was possible to identify the predictor variables with greatest impact to the carbon sink condition: radiation at the top of the atmosphere, sensible and latent energy fluxes and leaf area index. Thus, the ANN model with an ensemble of Data Science strategies can improve a better understanding of variability CO₂ fluxes and be a powerful tool to promote new knowledge.

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INTRODUCTION

The Amazon rainforest has a great influence on the global energy balance and carbon fluxes, being responsible for the net removal of approximately 4 million tons of carbon per year, via photosynthetic activity [1]. Climate change and deforestation have impacts on the carbon budget in Amazonia, transforming CO₂ sink areas into sources [2]. Given the complexity of the factors that govern the carbon exchange in the Amazon and its influence on biological processes, the use of Data Science strategies can promote a better understanding about the main environmental factors for different scenarios, and also, assist in public policies to mitigate the global warming effects.

OBJECTIVE

This study aims to identify the environmental factors that determine the temporal variability of carbon exchanges between the biosphere and the atmosphere in the Tapajós National Forest, in the Amazon, applying Data Science strategies in an integrated set of environmental data from energy and carbon fluxes and remote sensing data. The specific objective is to assess the influence of a selected set of environmental variables on the variability of carbon exchanges, with the use of an artificial neural network classification model to identify the variables with great impact on source, sink and neutrality scenarios in Tapajós National Forest.

MATERIALS AND METHODS

A daily dataset was integrated from ground-based carbon flux measurements and remote sensing data, considering the period between 2002 and 2006.

- Data sources (All variables used in this experiment are presented in Table 1):**
- LBA dataset (DOI: <https://doi.org/10.3334/ORNLDAAC/1842>)
 - Satellite Data MCD19A2 (DOI: <https://doi.org/10.5067/MODIS/MCD19A2.006>)
 - Satellite Data NOAA16 (DOI: <https://doi.org/10.7289/V5TT4P69>)

- Used libraries:**
- Data processing - *earth* library (available in R), *netCDF4* library (available in Python)
 - Deep Learning - *sklearn* and *keras* (both available in Python)

Artificial neural network model (ANN) - 4 layers (input layer, first intermediate layers with 11 neurons and activation function *relu*, second intermediate layer with 7 neurons and activation function *tanh*, output layer with 3 neurons and activation function *softmax*).

- Training and Testing:**
- Dataset split → 2/3 training set and 1/3 test set
 - Number of epochs adjusted with *keras.EarlyStopping()*
 - Batch size optimized with *sklearn.GridSearchCV()*
 - *Cross validation with 5 folds*

Variable	Description
NEE	Net ecosystem exchange of CO2
par	Photosynthetically active radiation
ta	Air temperature
LE	Latent heat flux corrected for the heat capacity of the air
H	Sensible heat flux corrected for the heat capacity of the air
prec	Accumulated daily precipitation
rh	Relative humidity
press	Atmospheric pressure
ws	Wind speed
h2o	Concentration of water in the atmosphere
Fh2o	Vertical transfer rate of water in the atmosphere
So	Incident radiation at the top of the atmosphere
ees	Saturation vapor pressure
ee	Vapor pressure
Rn	Incident global net radiation
LAI	Leaf area index
aod	Aerosol optical depth

Table 1: Variables used to training the Artificial neural network for NEE classification.

RESULTS

Accuracy - 63.81% (training) | 61% (testing) Average global score - 65.44% ± 4.06%

Figure 1 present the ANN predictions and below are presented Precision metrics:

	Precision	Recall	F1 Score
Neutral	58%	54%	56%
Sink	65%	72%	69%
Source	66%	61%	63%

In Figure 2 are presented the predictor variables with the main impact on the model. **So**, **LAI**, **LE** and **H** had stronger impact to predict **sink** scenarios, while **H**, **ee**, **LAI** and **So** had for **source** scenarios, and, **press**, **So** and **ee** for **neutral**.

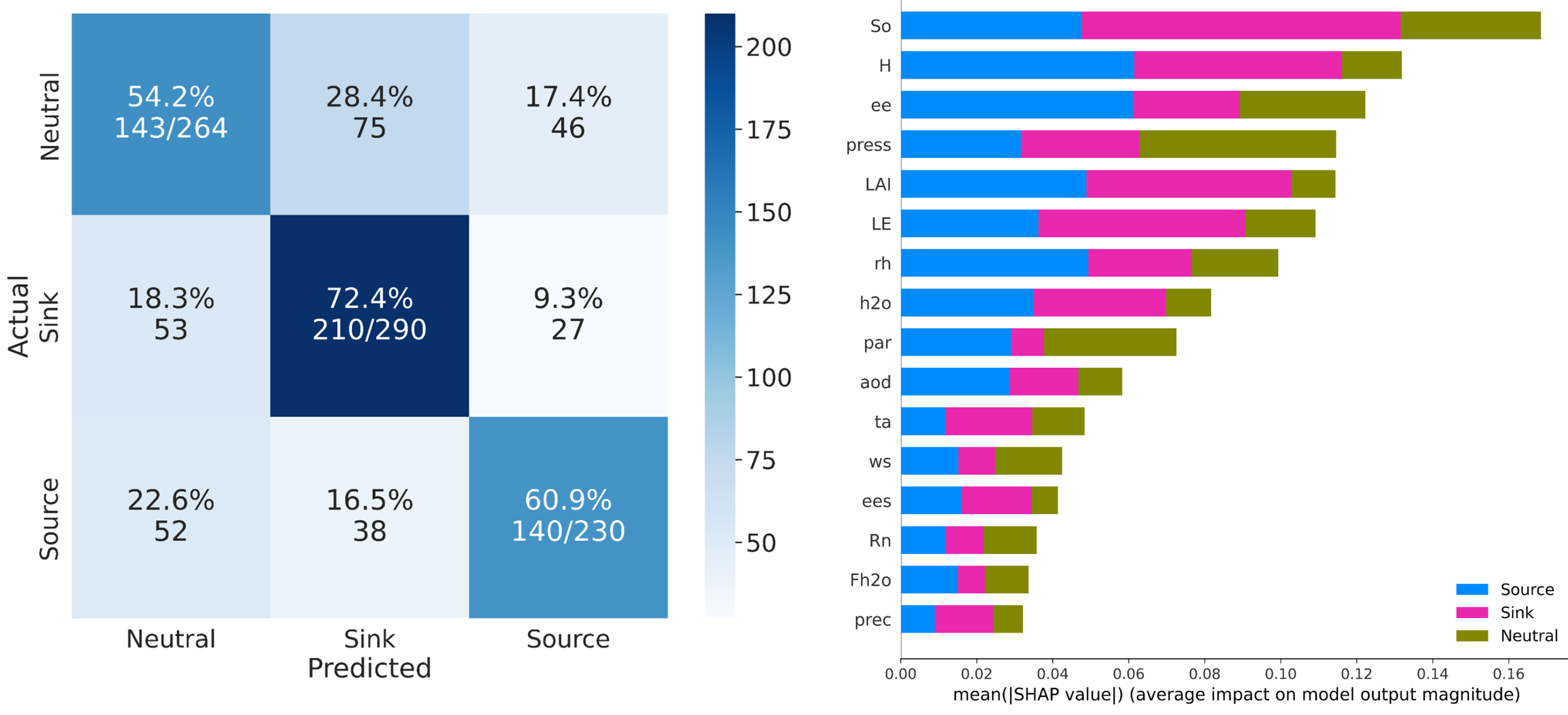


Figure 1: Confusion matrix.

Figure 2: Feature Importance accordingly with mean shap values.

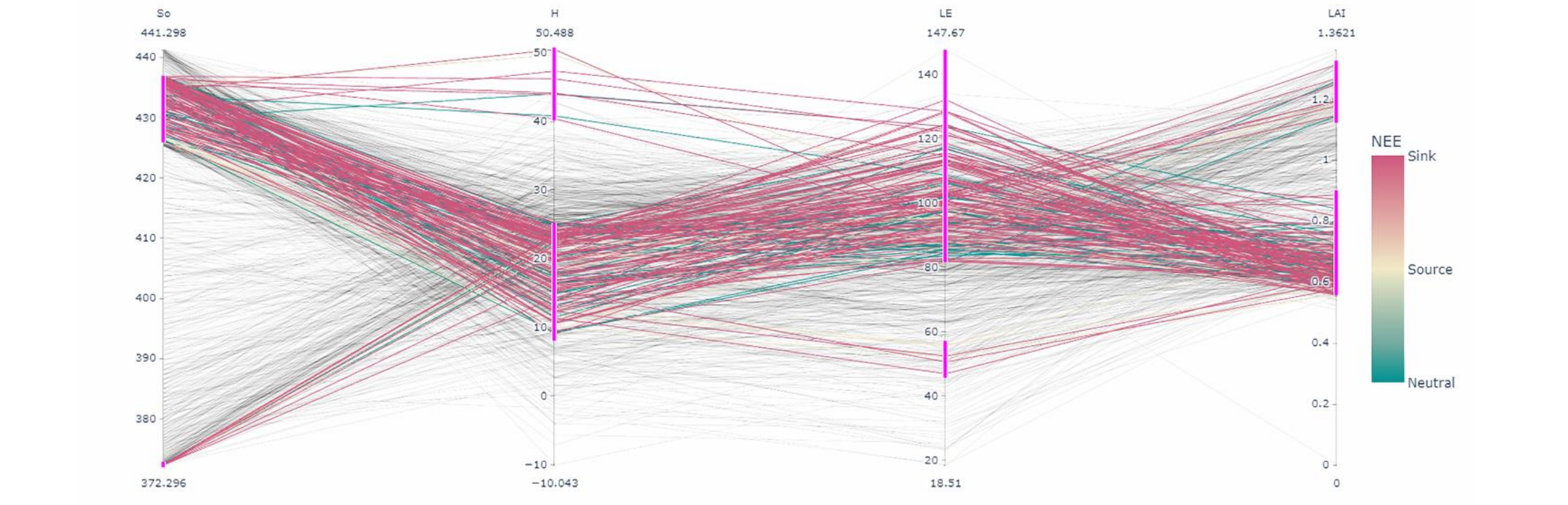


Figure 3: Example of parallel coordinates to identify environmental conditions which leads the forest act as a sink.

CONCLUSIONS

Although ANN model did not had a great performance, it is possible to find patterns which lead to each CO₂ exchange scenario, exploring the data, selecting those variables with strong impact for predictions (Figure 3). Thus, the ANN model with an ensemble of Data Science strategies can improve a better understanding of variability CO₂ fluxes and be a powerful tool to promote new knowledge. However, it is essential to have better environmental data availability and an integrated and multidisciplinary approach to net ecosystem exchange.

References:

[1] MALHI, Y. et al. Amazon Assessment Report 2021 - Chapter 6: Biogeochemical Cycles in the Amazon. 2021. <https://www.theamazonwewant.org/amazon-assessment-report-2021/>. Acess: 19/08/2022.

[2] GATTI, L. V. et al. Amazonia as a carbon source linked to deforestation and climate change. Nature, Nature Publishing Group, v. 595, n. 7867, p. 388–393, 2021.

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