Neural Network model for classification of net CO_2 fluxes scenarios in Tapajós Forest, in Amazon

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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 CO_2 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 → ⅔ training set and ⅓ 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.

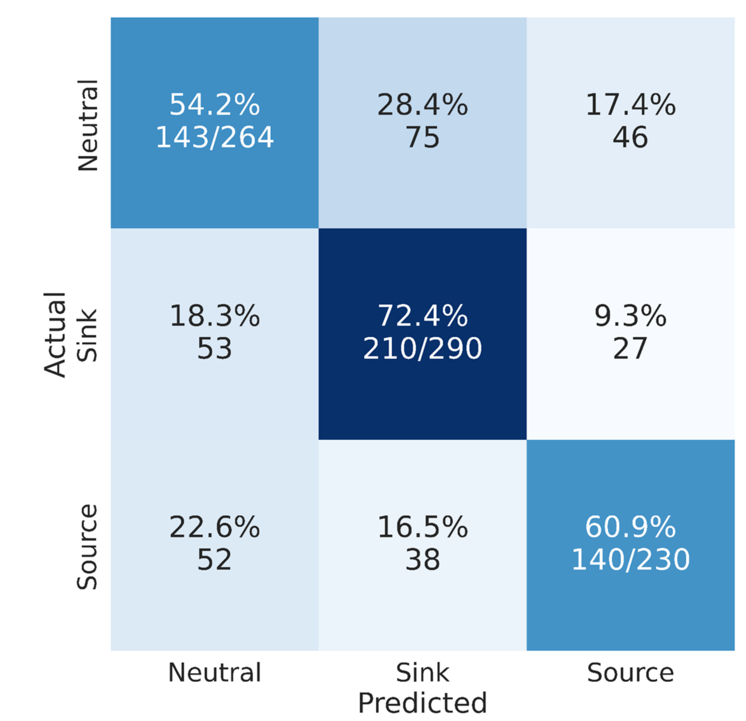

Figure 1: Confusion matrix.

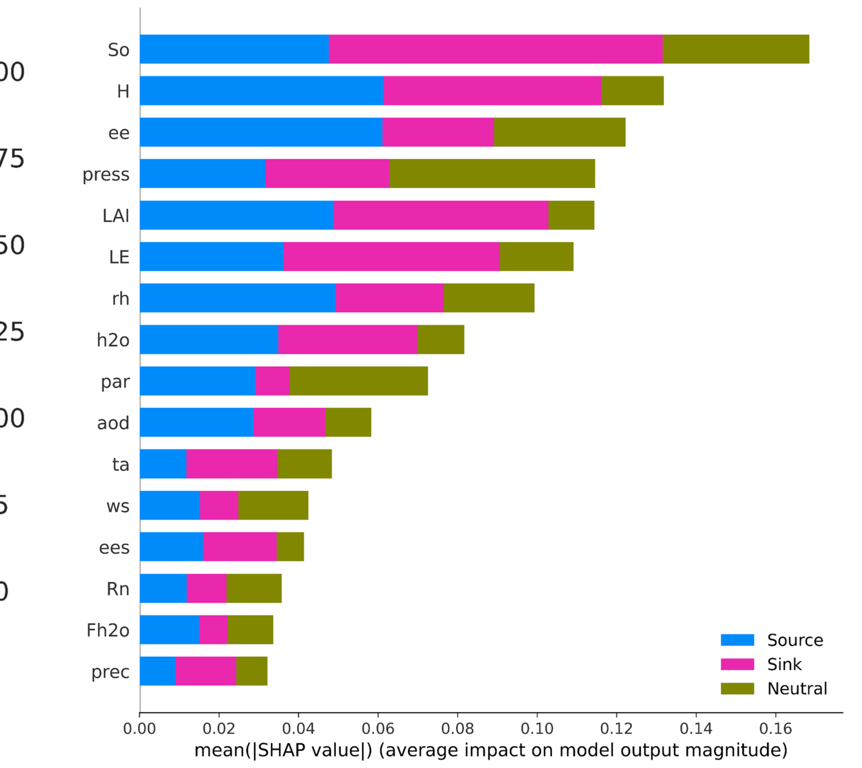

Figure 2: Feature Importance accordingly with mean shap values.

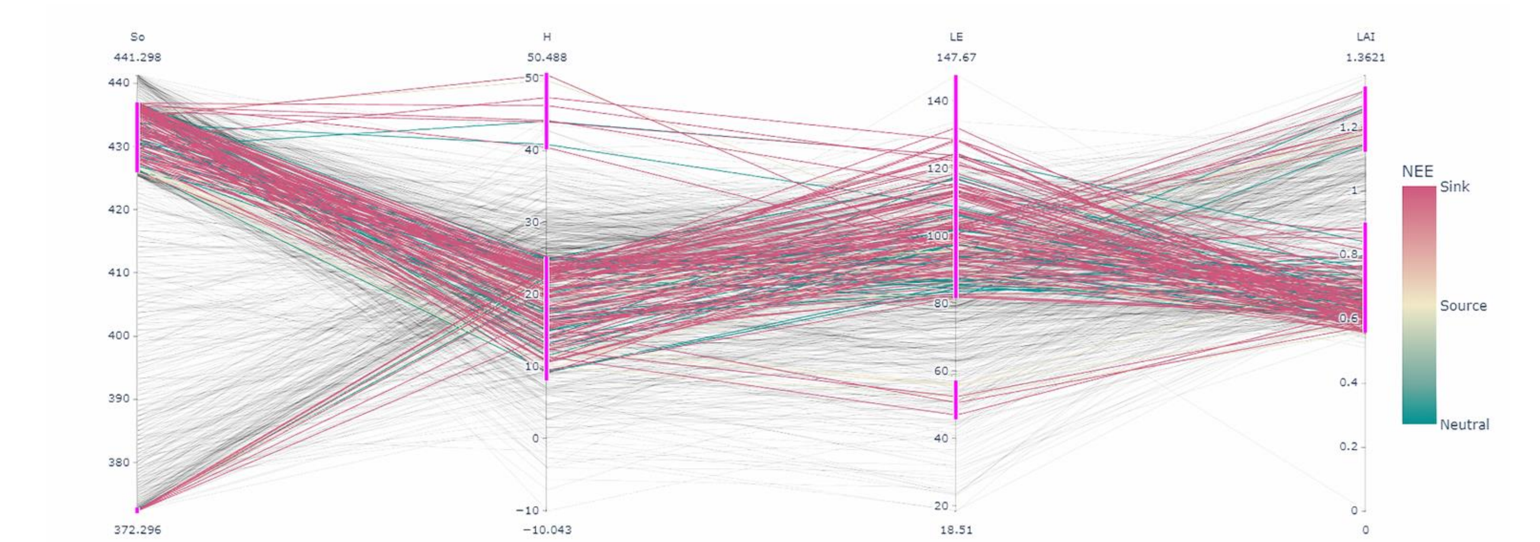

Figure 3: Example of parallel coordinates to identify environmental conditions which leads the forest act as a sink.

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***.

CONCLUSIONS

Although ANN model did not had a great performance, it is possible to find patterns which lead to each CO_2 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 CO_2 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:

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Acknowledgements:

Gratefully acknowledge support of the RCGI, hosted by University of São Paulo (USP) and sponsored by FAPESP (grants 2014/50279-4 and 2020/15230-5) and Shell Brasil, and the strategic importance of the support given by Brazil's National Oil, Natural Gas and Biofuels Agency (ANP) through the R&D levy regulation.

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Data Science and Machine Learning applied to the fields of ecology, environment and socio-economics (supported by PARCEC) , 04 October 2022, São Paulo, Brazil