Neural networks to estimate and map world forest foliar elemental composition and stoichiometry

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Introduction: Barrel theory

N, P and K stocks, fluxes and availability improve the projections about the potential impacts of global change, in particular of global warming, on C-cycle (Jiang et al, 2017; Sardans & Peñuelas, 2015)

Only gross N and P concentration maps in vegetal tissues and any K data is available at the moment
Methods: Data gathering & classification

Natural conditions:
- 230 published articles
- TRY plant trait database
- ICP forest
- TTT Tundra Trait Team
- IFC Catalan Forestal Institute

Biomas:
- Boreal
- Temp. deciduous broadleaves
- Temp. evergreen broadleaves
- Temperate coniferous
- Tropical deciduous
- Tropical evergreen

Georeferenced plots

N% P% K% 30530

WWF biome categories
Methods: predictors

73 predictor maps

Climatic data:
WorldClim (Fick & Hijmans, 2017)

Aridity & evapotranspiration:
CGIAR-CSI (Trabucco & Zomer, 2019)

Soil gridded data (Sangguan et al. 2014)

N deposition: (Ackerman et al. 2018)

P deposition: (Wang et al. 2017)

N, P and K sampled points. Color separation by latitudinal groups based on WWF ecoregion map (Olson et al, 2001)
Methods: Neural Networks = NNTools

- NN structure
- \[[\text{Training (80\% samples)}] \times 500\]
- Test (20\% samples)
- Predictions

\[R^2\] - Performance

- Variables importance
- Variables response
- Prediction maps

\[\times 100\] - glm's
Results: Nitrogen

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<th>Bioma</th>
<th>$R^2$</th>
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<tr>
<td>Bor</td>
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<td>TempDB</td>
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<tr>
<td>TempC</td>
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<tr>
<td>TropD</td>
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<tr>
<td>TropE</td>
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Results: Phosphorus

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Results: Potassium

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Results: Glm’s, general issues

- Tropical: influenced by seasonality (both, temperature and precipitation)
  - N: + seasonality = $\downarrow$ N
  - P: + seasonality = $\uparrow$ P
  - K: + seasonality = $\downarrow$ K
- Temperate: influenced by the aridity, high temperatures and water availability
  - N: + aridity = $\downarrow$ N
  - P: + aridity = $\downarrow$ P
  - K: + aridity = $\uparrow$ K (if enough water to K absorption)
- Boreal: N and P very influenced by summer temperature and precipitation conditions and K by N deposition
  - N: + precipitation and temperature = $\uparrow$ N
  - P: + temperature = $\uparrow$ P
  - K: + N deposition = $\downarrow$ K
Discussion

Which kind of variables is more important?

Mean by group of the weighted importance of the variables by eigenvalue of the 5 more important axes in a PCA

1. Climate variables
2. Deposition variables
3. Soil variables
Discussion

Does leaves follow the soil age hypothesis?

Violin plots of the predicted values of N and P gathered by USDA Soil Taxonomy orders (1999)

Older the soil, $\uparrow$ N and $\downarrow$ P
Conclusions

With our models it is possible to:

- Obtain **global maps at 1km resolution** of N,P,K % in leaves of woody plants with $R^2$ between 0.11 and 0.50
- Which **variables determine the global patterns** of N,P,K distribution in leaves of woody plants and **how**
- **Leaves stoichiometry follows the soil age hypothesis**
- Determine that **climatic conditions** are generally **more important than deposition or soil** characteristics to determine leaves stoichiometry
Bibliography


Thank you

Why do plants hate math?
Because it gives them square roots.

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