Afforestation and groundwater use in South American grasslands: impacts on productivity and salinity across a rainfall gradient

Nosetto M, Jobbágy E, Tóth T, Jackson R, Oyarzabal M.

- Grupo de Estudios Ambientales - UNSL & CONICET. ARGENTINA
- Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences. HUNGARY
- Department of Biology and Nicholas School of the Environment and Earth Sciences, Duke University. USA
- Facultad de Agronomía. UBA. ARGENTINA
The Pampas

- Vast flat grassland area
- Originally treeless region
- Temperate and (sub)humid climate (15 - 20 °C, 600 - 1600 mm/year)
- Shallow watertables
- Most important land-use: native grasslands, pastures and crops
Afforestation in The Pampas

The process  Grassland $\rightarrow$ Tree plantation

Pines and Eucalyptus (fast growth) increased 3X 1990-2000 in MERCOSUR (Arg – Uru – Bra)

Target areas

Remaining grasslands of Argentina, Uruguay and Brazil
- not cropped areas (steep slope, flooding, massive bedrock, etc)
- high precipitation level (high primary productivity)

Drivers
High carbon gains
Increasing need of forest products
Governmental policies
Low land and labour force costs
Increased C gains with afforestation

Carbon Aboveground net primary productivity (Kg ha\(^{-1}\) y\(^{-1}\))

<table>
<thead>
<tr>
<th>Water balance (mm yr(^{-1}))</th>
<th>EVI values (MODIS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 600</td>
<td>0.60</td>
</tr>
<tr>
<td>400 – 600</td>
<td>0.40</td>
</tr>
<tr>
<td>200 – 400</td>
<td>0.20</td>
</tr>
<tr>
<td>0 – 200</td>
<td>0.00</td>
</tr>
<tr>
<td>-200 – 0</td>
<td>0.00</td>
</tr>
<tr>
<td>-400 – -200</td>
<td>0.00</td>
</tr>
<tr>
<td>-600 – -400</td>
<td>0.00</td>
</tr>
<tr>
<td>-800 – -600</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Satellite surrogate of NPP

- Tree plantations
- Grasslands

Map showing water balance and EVI values distribution in South America regions.
The cost of higher water losses with afforestation
The cost of higher water losses with afforestation

-62%  +28%  0-1  2-3  4-5  6-8  9

Tree plantation age (year)

ET (mm day⁻¹)

grassland

E. grandis

Tree plantation

grassland

-62%  +28%

●

[Diagram showing water losses and afforestation impact]
The cost of higher water losses with afforestation
The cost of higher water losses with afforestation
The cost of soil and groundwater salinization with afforestation

**Electric Conductivity (dS/m)**

- Soil salinization
  - 6 Kg/m2 salt in 50 yrs

**Mechanism:**
- Transpiration +
- Root exclusion of solutes
The cost of soil and groundwater salinization with afforestation

The climatic control of salinization

Water Balance (mm yr⁻¹)
- < -800
- -800 – -600
- -600 – -400
- -400 – -200
- -200 – 0
- 0 – 200
- 200 – 400
- 400 – 600
- > 600

Soil ECa (dS m⁻¹)
- Grasslands
  - Tree plantations
  - 2.34 dS m⁻¹
  - 0.34 dS m⁻¹
  - p<0.001
  - P>0.1
- Grassland
  - 1.14 dS m⁻¹
  - 0.39 dS m⁻¹
The cost of soil and groundwater salinization with afforestation

The biological (i.e. forest species) control of salinization

Broadleaf evergreen
- *E. camaldulensis*
- *E. cinerea*
- *E. melliodora*

Conifers
- *P. radiata*
- *C. deodara*
- *C. sempervirens*

Broadleaf deciduous
- *Q. robur*
- *M. pomifera*
- *P. deltoides*

C. cunninghamiana
The cost of soil and groundwater salinization with afforestation

The biological (i.e. forest species) control of salinization

Groundwater electrical conductivity (dS m⁻¹)

Salinity Tolerance (dS m⁻¹)

EC (dS m⁻¹)

27.1

12x

2.15

R² = 0.79
Conclusions

- Afforestation on the native grasslands of The Pampas increases the aboveground primary productivity, specially where groundwater is available.

- Afforestation increases the evaporative water losses (40-80% on average)

- The higher water use of tree plantations may imply groundwater consumption

- Intense GW use by tree plantations may switch the hydrological regime from a recharge to a net discharge situation, leading to soil and groundwater salinization

- Climate dictates the onset of salinization in afforested grasslands at the regional scale

- Tolerance to salinity is a key biological driver of salinization at the stand scale, influencing salt accumulation levels in the groundwater-vadose zone system
Thanks !!!!

http://gea.unsl.edu.ar