Strategies for greenhouse gas emissions mitigation in Mediterranean agriculture: A review


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AGEE Special Issue on GHG mitigation in Mediterranean cropping systems

Special Issue: "Mitigation and Quantification of GHG in Mediterranean cropping systems"

Agriculture, Ecosystems & Environment (Dec. 2016)
14 international contributions
• Temporal gap between maximum irradiance and temperature (early summer) and maximum water availability (winter).
• Low organic matter content of most cropped soils

Low productivity of agricultural soils

Effect on N emission processes
Irrigated vs rainfed systems

- Irrigation: key factor affecting soil microbial processes leading to GHG & reactive N emissions (e.g. NOₓ).
- Main processes: nitrification & nitrifier denitrification (Aguilera et al., 2013; AGEE)
- Irrigation system highly impacts on N₂O & NOₓ emissions (Aguilera et al., 2013; AGEE)
- N₂O EFs ≤ IPCC (10 times lower in rainfed).
- Impact on C footprint of Mediterranean agricultural goods (Cayuela et al., 2016; AGEE) Presented on Thursday by L. Lassaletta
Data & information collection

Based on:

- Expert judgement (Mediterranean & temperate)
- Scientific literature review

1. Agronomic mitigation measures
   - $N_2O$
   - Potential of mitigation
   - SOC
   - Side effects
   - $CH_4$
   - Barriers & opportunities for implementation

2. Structural mitigation options
   - Changes in diet
   - Food waste

Direct GHG Mitigation options

Information on:
### Agronomic mitigation measures

<table>
<thead>
<tr>
<th>Group of measures</th>
<th>Mitigation measure</th>
<th>Direct GHG abated</th>
<th>% of mitigation</th>
<th>Potential cost (2)</th>
<th>Potential benefit (2)</th>
<th>Potential positive and negative side-effects (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agronomic measures (1)</td>
<td>Optimal fertilization</td>
<td>N₂O</td>
<td>40-50</td>
<td>**</td>
<td>***</td>
<td>Indirect N₂O, NO₃⁻, NH₃</td>
</tr>
<tr>
<td></td>
<td>Substitution synthetic fertilizers by manures</td>
<td>N₂O</td>
<td>20-50</td>
<td>***</td>
<td>**</td>
<td>Indirect N₂O, NO₃⁻, NH₃, Sequestration</td>
</tr>
<tr>
<td></td>
<td>Injection of slurry</td>
<td>C seq.</td>
<td>0-10</td>
<td>**</td>
<td>**</td>
<td>Indirect N₂O</td>
</tr>
<tr>
<td></td>
<td>Immediate incorporation of manures after application</td>
<td>C seq/N₂O</td>
<td>0-10</td>
<td>**</td>
<td>**</td>
<td>Indirect N₂O</td>
</tr>
<tr>
<td>Inhibitors</td>
<td>Use of nitrification inhibitors</td>
<td>N₂O</td>
<td>20-50</td>
<td>***</td>
<td>**</td>
<td>Indirect N₂O, CO₂, NO, NO₂⁻, NH₃</td>
</tr>
<tr>
<td></td>
<td>Use of urease inhibitors</td>
<td>N₂O</td>
<td>30-60</td>
<td>***</td>
<td></td>
<td>Indirect N₂O, CO₂, NO, NH₃</td>
</tr>
<tr>
<td>Crop rotations and cover crops</td>
<td>Cover crops</td>
<td>C seq.</td>
<td>0-10</td>
<td>**</td>
<td>**</td>
<td>CO₂, Indirect N₂O, CO₂</td>
</tr>
<tr>
<td></td>
<td>Crop rotations</td>
<td>C seq.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Improved irrigation technology</td>
<td>N₂O/CH₄</td>
<td>50-70</td>
<td>**</td>
<td>**</td>
<td>Indirect N₂O</td>
</tr>
<tr>
<td>Soil tillage</td>
<td>Low/no tillage</td>
<td>C seq.</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>CO₂, NO₃⁻, NH₃</td>
</tr>
<tr>
<td>Crop residues and agro industry by-products</td>
<td>Crop residues</td>
<td>C seq.</td>
<td>50-70</td>
<td>*</td>
<td>**</td>
<td>CO₂, NH₃, CO₂</td>
</tr>
</tbody>
</table>

- **N** management (adjusted N fertilization; substitution of synthetic fertilizers by solid manures)
- **Water management** (drip irrigation)
- NI and U inhibitors
- Crop rotations and CCS
- Reduced soil tillage
- Management of crop residues and by-products
By cropping system: rainfed & irrigated systems

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Main component of radiative forcing</th>
<th>Main mitigation practice</th>
<th>Other pollutants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herdaceous</td>
<td>Machinery/external inputs; C seq. (NT)</td>
<td>Reducing fuel consumption and external inputs, reduced tillage crop rotations (including legumes), adjusted N rates, Nis</td>
<td>Increased NH₃, Increased NH₄, NO₃⁻</td>
</tr>
<tr>
<td>Fruit orchards</td>
<td>C sequestration</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Rice</td>
<td>NA</td>
<td>NA</td>
<td>Increased N₂O</td>
</tr>
</tbody>
</table>

- **N₂O** as main contributor to total GHG budget in **irrigated systems**. Agronomic practices with more potential (water and N fertilizer management).

- **Indirect GHG emissions** more important over the total balance in **rainfed**. Management practices both in the production system & upstream.
Beyond the plot: Enlarging the scope/boundaries of the cropping systems (LCA)

Case study:

- Effect of water availability (energy for pumping groundwater).
- N fertilizer use. High N: GHG from fertilizer production

Drip irrigation only effective in a energy costly scenario
### Barriers for implementation

<table>
<thead>
<tr>
<th>Agronomic Measures</th>
<th>Overall Constraints</th>
<th>Technical</th>
<th>Economic</th>
<th>Social (2)</th>
<th>Environmental (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjust N fertilization to crop needs</td>
<td>LOW</td>
<td>Soil analysis needed to adjust dosage. Need to know adjusted crop requirements</td>
<td>Potential increase in labor costs (e.g., spirt application) and soil analysis</td>
<td>Perception of decreased productivity</td>
<td>NA.</td>
</tr>
<tr>
<td>Substitute synthetic fertilizers by manures and slurries</td>
<td>MEDIUM</td>
<td>Need to know adjusted crop requirements. Need of adequate equipment (for incorporation of slurries)</td>
<td>Transport and application costs. New equipment</td>
<td>Legal restrictions (EU Nitrates Directive 91/676/EEC) – (i.e., use, management, treatment and transportation) Bad smells. Unlikely applicable to areas with mixed farming systems, Perceptions of decreased productivity. Not for all crops</td>
<td>Potential pollution and health issues.</td>
</tr>
<tr>
<td>Fertilization &amp; improved irrigation technology</td>
<td>HIGH</td>
<td>New infrastructure associated with conversion. Maintenance difficulties (irrigation)</td>
<td>Initial expensive investment costs</td>
<td>N/A.</td>
<td>Potential accumulation of heavy metals in crops (i.e., rice).</td>
</tr>
<tr>
<td>Nitrification &amp; urease inhib</td>
<td>HIGH</td>
<td></td>
<td>Increase of denitrification costs</td>
<td>Not widely spread among neighboring farmers</td>
<td>N/A.</td>
</tr>
<tr>
<td>Biochar</td>
<td>LOW</td>
<td>Lack of experiments at local conditions</td>
<td>Expensive product ($25 per kilo)</td>
<td>Lack of knowledge on how to produce on-site; Lack of regulations</td>
<td>N/A.</td>
</tr>
<tr>
<td>Composted</td>
<td>HIGH</td>
<td>Access/availability</td>
<td>Transport and</td>
<td>Specific knowledge required</td>
<td>Pollution issues</td>
</tr>
</tbody>
</table>

#### Technical:
- N adjustments. Soil analysis
- Improved irrigation: new infrastructure.

#### Economic:
- N adjustments. Labor costs. Nis (high costs).
- Improved irrigation: Initial investment.

#### Social:
- N adjustments. Social perceptions. Legal restrictions.
Structural measures

- Decrease animal protein consumption (move to Mediterranean diet: 40% total protein).
- Reduce food waste (c. 33%).
Conclusions

• **N₂O emissions** of Mediterranean cropping systems are generally lower than those observed in temperate ones, though the potential for mitigation is high.

• **Variable climatic conditions** are common in Mediterranean areas. This affects not only N₂O emission processes but the effectiveness of mitigation strategies (e.g. nitrification inhibitors).

• **Optimized N fertilization** and **irrigation** show a large potential for N₂O mitigation.

• Organic fertilization suitable alternative for reducing GHG emissions without yield penalties in irrigated systems.

• Measures designed to increase **C sequestration** through judicious management of exogenous or endogenous C sources: high mitigation potential in Mediterranean cropping systems (permanent crops). Irrigated annual crops are at risk of losing SOC if they are not adequately managed.

• **CH₄ fluxes** from paddies are controlled by management of the water table and organic inputs.

• Implementation will require effective **regional and international policies**, closer collaboration between scientists, stakeholders and farmers, and enhanced public awareness and engagement.
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Thanks for your attention