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

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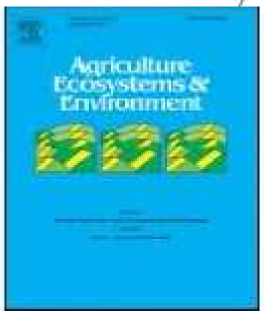
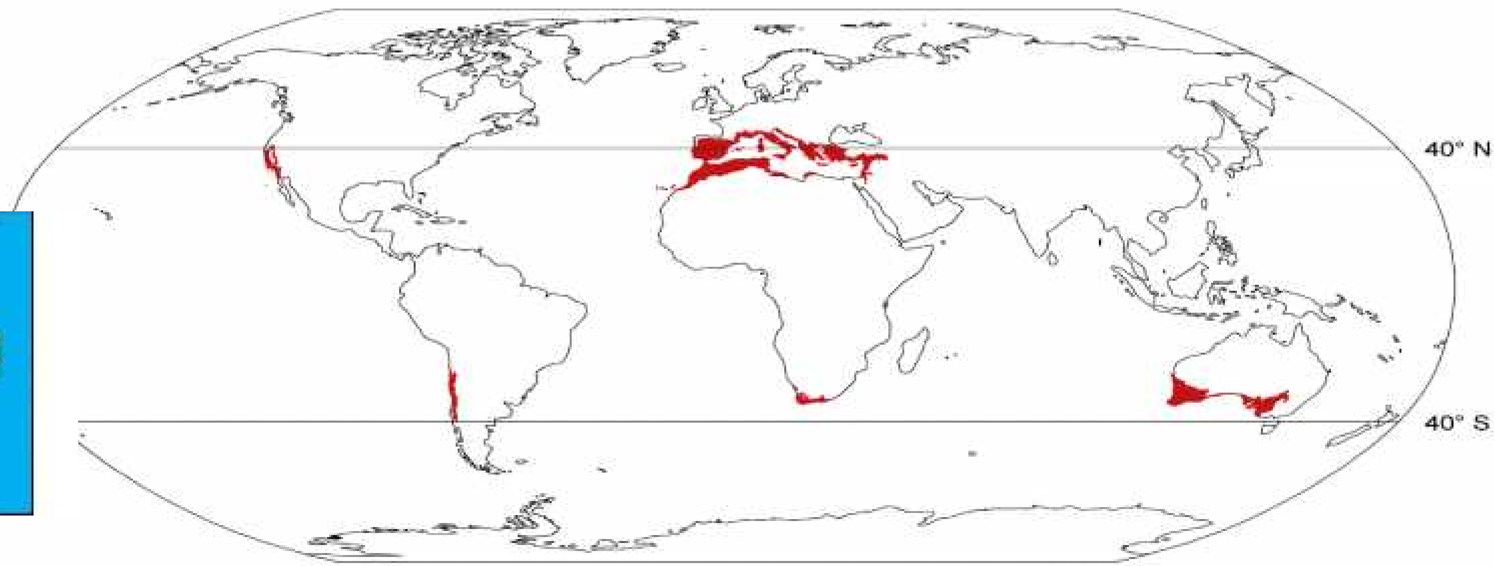
AGEE Special Issue on GHG mitigation in Mediterranean cropping systems



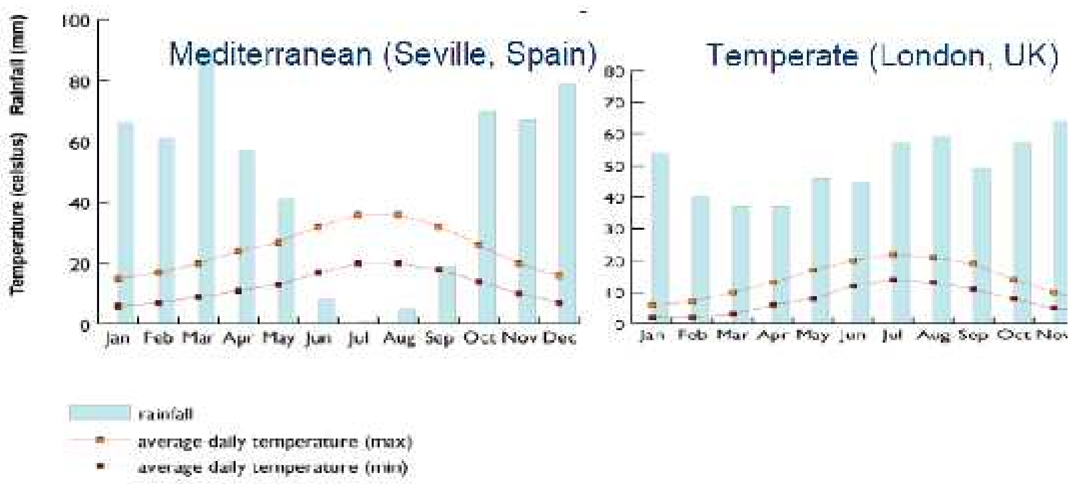


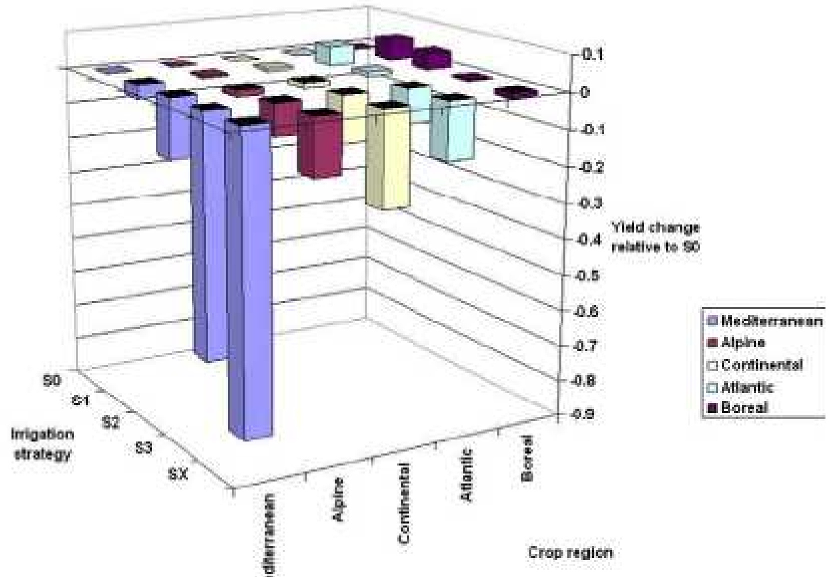
Special Issue: **"*Mitigation and Quantification of GHG in Mediterranean cropping systems*"**
Eds. Alberto Sanz-Cobena, Luis Lassaletta, Josette Garnier and Pete Smith. Eds.

Agriculture, Ecosystems & Environment (Dec. 2016)

14 international contributions

Mediterranean climate & agriculture





Wriedt et al. (2009) J. Hydrol.

- 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

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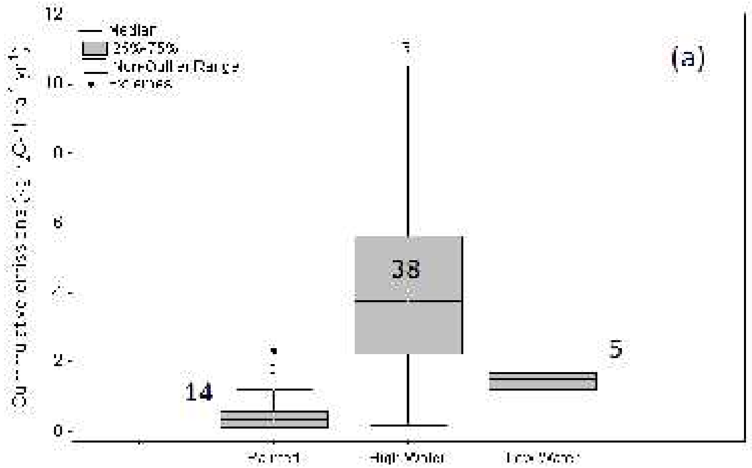
Irrigated vs rainfed systems

- Irrigation: key factor affecting soil microbial processes leading to GHG & reactive N emissions (e.g. NO_x).
- Main processes: nitrification & nitrifier denitrification (Aguilera et al., 2013; AGEE)
- Irrigation system highly impacts on N_2O & NO_x emissions (Aguilera et al., 2013; AGEE)
- N_2O EFs ≤ IPCC (10 times lower in rainfed).



Aguilera et al. (AGEE) 2013

- Impact on C footprint of Mediterranean agricultural goods (Cayuela et al., 2016; AGEE) *Presented on Thursday by L. Lassaletta*

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Data & information collection

Based on:

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

1. Agronomic mitigation measures

N_2O
SOC
CH_4

- Potential of mitigation
- side effects
- barriers & opportunities for implementation

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

Information on:

Direct GHG Mitigation options

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Agronomic mitigation measures

Group of measures	Mitigation measure	Direct GHG abated	% of mitigation	Potential cost (2)	Potential benefit (2)	Potential positive and negative side-effects (3)				
								Other pollutant on farm		
						GHG mitigation out farm	GHG increase outside the farm	Reduced pollutant	Increased pollutant	Crop yield change on farm
Agronomic measures (1)										
Optimal fertilization	Adjust N fertilization to crop needs	N_2O	30–50	**	*****	Indirect N_2O		NO_3^-, NH_3		No effect
	Fertigation	N_2O	30–50	***	****	Indirect N_2O		NO_3^-		Increase
	Substitute synthetic fertilizers by manures	N_2O	20–50	**	****	Indirect N_2O, CO_2	CH_4	P, NO_3, C sequestration	NH_3, heavy metals	No effect
Manures and slurries	Injection of slurries	C seq.	0–10	****	**	Indirect N_2O		NH_3	NO_3^-, CH_4	Decrease
	Immediate incorporation of manures after application	C seq./N_2O	0–10	**	**	Indirect N_2O		NH_3	NO_3^-, CH_4	Increase
Inhibitors	Use of nitrification inhibitors	N_2O	30–50	****	***	Indirect N_2O	CO_2[c]	NO, NO_3^-	NH_3	Increase[a]
	Use of urease inhibitors	N_2O	30–60	****	***	Indirect N_2O	CO_2[c]	NO, NH_3		Increase
Crop Rotations and cover crops	Cover crops	C seq.	0–10	**	***	CO_2[c]/Indirect N_2O		NH_3, NO_3^-, P		Variable
	Crop Rotations	C seq.	–	*	***	CO_2[c]		–	–	Increase
Irrigation	Improved Irrigation technology	N_2O/CH_4[b]	50–70	**	***	Indirect N_2O		NO_3	NO, CH_4[b]	Increase
Soil tillage	Low/no tillage	C seq.	–	**	***	CO_2[c]		NO_3, NH_3	N_2O	Increase
Crop residues and agro industry by-products	Crop residues mulching	C seq.	50–70	*	**	CO_2[c]		NH_3		Long-term increase
	Crop residues	C seq.	50–70	*	*	CO_2[c]		NH_3	CH_4[d]	Long-term

- **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

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By cropping system: rainfed & irrigated systems

Crop type	Main component of radiative forcing		Main mitigation practice		Other pollutants	
	Rain-fed	Irrigated	Rain-fed	Irrigated	Rain-fed	Irrigated
Herbaceous	Machinery/ external inputs; C seq. (NT)	N_2O	Reducing fuel consumption and external inputs, reduced tillage crop rotations (including legumes), adjusted N rates, Nis	Water management (e.g. drip irrigation), N fertilization (e.g. adjusted N rates, Nis)	Increased NH_3	Increased NH_3, NO_3^-
Fruit orchards	C sequestration	N_2O	NA	Cover crops, pruning crop residues	NA	NA
Rice	NA	CH_4	NA	Water management, straw management mitigation strategies	NA	Increased N_2O

- **N_2O** 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.

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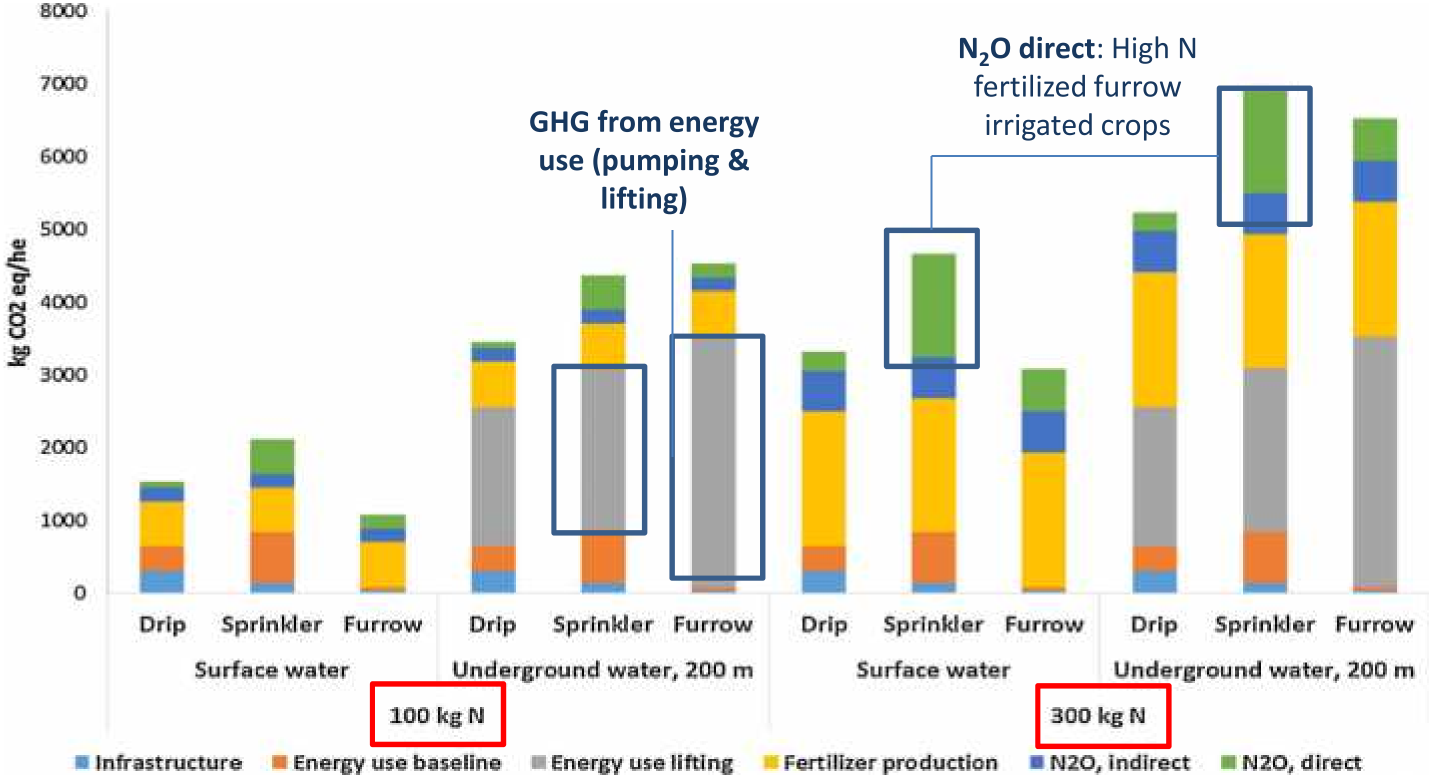
Beyond the plot: Enlarging the scope/boundaries of the cropping systems (LCA)



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

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Barriers for implementation

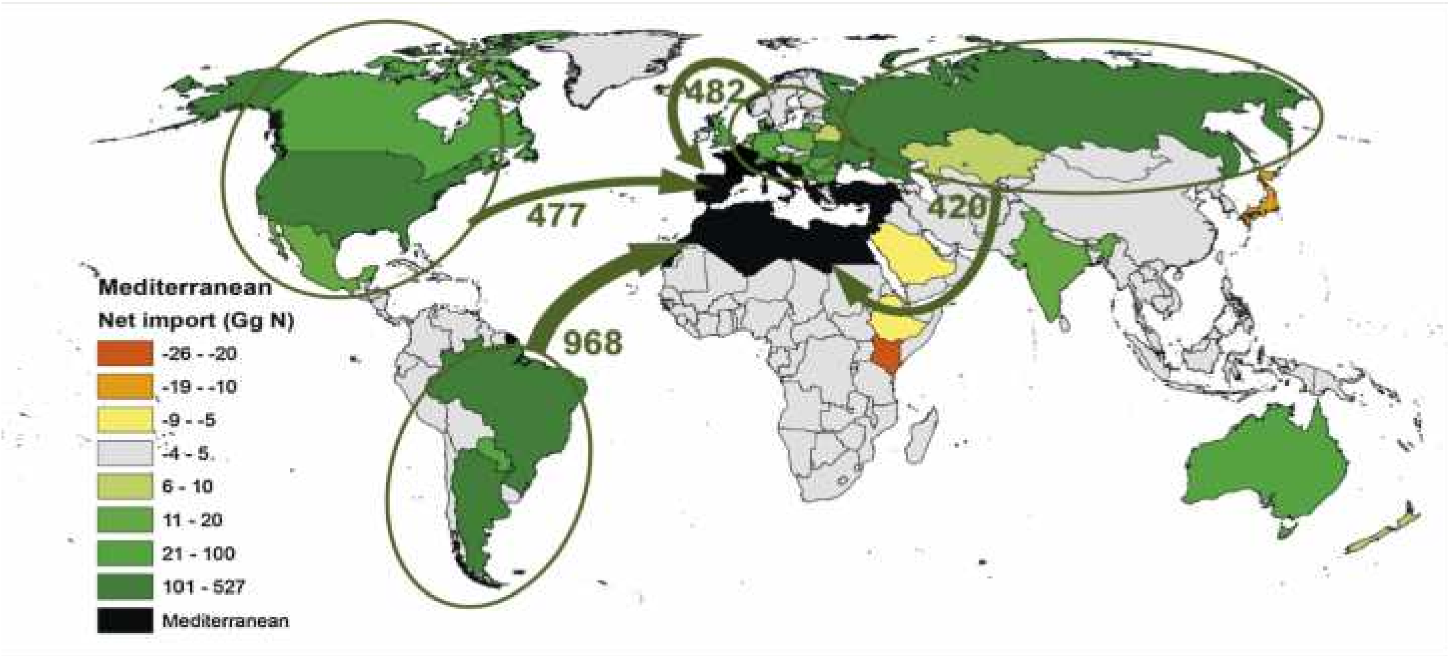
Agronomic Measures	Ove-rall (1)	Constraints			
		Technical	Economic	Social (2)	Environmental (3)
Adjust N fertilization to crop needs	Low	Soil analysis needed to adjust dosage. Need to know adjusted crop requirements	Potential increase in labor costs (e.g. split application) and soil analysis	Perception of decreased productivity	N.A.
Substitute synthetic fertilizers by manures and slurries	Medium	Need to know adjusted crop requirements Need of adequate equipment (for incorporation of slurries)	Transport and application costs New equipment	Legal restrictions (EU Nitrates Directive 91/676/ EEC) – (i.e. use, management, treatment and transportation) Bad smells Only applicable to areas with mixed farming systems Perception of decreased productivity	Potential pollution and health issues
Fertigation & improved irrigation technology	High	New infrastructure associated with conversion Maintenance difficulties (fertigation)	Initial expensive investment costs	Not for all crops	Potential accumulation of heavy metals in crops (i.e., rice)
Nitrification & Urease inhib.	High	N.A.	Increase of fertilization costs	Not widely spread among neighboring farmers	N.A.
Biochar	Low	Lack of experiments at local conditions	Expensive product (2$ per kilo)	Lack of knowledge on how to produce it on-site; Lack of regulations	N.A.
Composted	High	Access/availability	Transport and	Specific knowledge required	Pollution issues

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

- **N_2O 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 N_2O emission processes but the effectiveness of mitigation strategies (e.g. nitrification inhibitors).
- **Optimized N fertilization** and **irrigation** show a large potential for N_2O 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.
- **CH_4 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