Agriculture, Ecosystems and Environment xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Editorial

Mitigation and quantification of greenhouse gas emissions in Mediterranean cropping systems

1. Introduction

Mediterranean climate, found in some regions between latitudes 30° and 45°, is characterized by having mild winters and warm and dry summers. Over one half of the area with Mediterranean-type climate worldwide is found in the Mediterranean Sea Basin, but it is also present in four other regions of the world namely California (USA), Central Chile, the Cape region of South Africa, and South-West Australia (Aschmann, 1973). Precipitation during the summer period, when highest temperatures occur, is scarce, and crop yields are boosted by irrigation more than in temperate areas (Wriedt et al., 2009). Climate models have forecast a rise in temperatures and severe water scarcity, with major impacts on crop yields (Bindi and Olesen, 2011; Iglesias et al., 2011). In Mediterranean Europe, driven by climate change, annual precipitation has decreased whereas the frequency and intensity of extreme weather events (e.g. droughts, floods) increased, thus enhancing land degradation processes and the risk of desertification (Diodato et al., 2011; Garcia-Ruiz et al., 2011). The development of effective mitigation and adaptation strategies are therefore crucial for the future of the Mediterranean region. Additionally, the understanding of Mediterranean agroecosystems is also interesting in the context of increasing temperature and decreasing precipitation in many temperate areas (Trnka et al., 2011), which could lead to a process of "mediterraneization". Indeed, climate models indicate that the Mediterranean climate range could expand by 15–32% in the Mediterranean basin and by 29–53% in South America (Klausmeyer and Shaw, 2009).

The temporal gap between maximum irradiance and temperature (early summer) and maximum water availability (winter), added to the specifically low organic matter (OM) content of cropped Mediterranean soils, are important drivers of the typically low productivity of rain-fed crops (Aguilera et al., 2013a). On the other hand, irrigated agriculture benefits from the solar radiation and extended frost-free periods to make these areas capable of high crop yields. Therefore, influenced by edaphic and climatic conditions, Mediterranean agriculture is characterized by contrasting cropping systems under rainfed or irrigated conditions, and large surfaces of permanent crops. Specific agro-climatic conditions suggest that biochemical processes responsible for soil greenhouse gas (GHG) emissions, which show distinct patterns in Mediterranean agro-ecosystems, for example in terms of carbon (C) sequestration (Aguilera et al., 2013a) and nitrous oxide (N_2O) emissions (Aguilera et al., 2013b). These specific patterns potentially affect the estimation of the net GHG footprint of agricultural products, as shown by life cycle assessment studies incorporating Mediterranean N_2O emission factors (Biswas et al., 2008; Aguilera et al., 2015a,b) and C sequestration (Venkat, 2012; Aguilera et al., 2015a,b). As a general trend, the role of N_2O in the GHG balance is relatively minor due to low N inputs and low emission factor (EF), while the role of C sequestration can be very relevant depending on management (Aguilera, 2016). These findings are also supported by another study directly measuring soil GHG fluxes (Guardia et al., 2016a). An increasing body of research has addressed GHG emissions in Mediterranean cropping systems, contributing to identify the best GHG mitigation practices. However, the level of understanding of soil processes responsible for GHG emissions and of the potential of agronomic practices to mitigate GHG emissions is still relatively low, for example when compared to that of temperate areas, indicating a need to synthetize and expand this knowledge. These are the two main objectives of this Special Issue.

The Special Issue begins with a descriptive review aiming to synthesize and analyze the most promising strategies for GHG mitigation in Mediterranean cropping systems. Sanz-Cobeña et al. (in this issue) made an integrated assessment of management practices on mitigating each component of the total GHG budget (N_2O and methane (CH_4) emissions, and C sequestration) of production systems, considering potential side-effects, as well as regional barriers and opportunities for their implementation. This analysis allowed proposing best strategies to abate GHG emissions, while sustaining crop yields and mitigating other sources of environmental pollution.

2. Nitrous oxide emissions

A set of seven papers focuses on N_2O emissions. Cayuela et al. (in this issue) performed a meta-analysis of N_2O emissions from Mediterranean cropping systems to propose more robust and reliable regional emission factors (EFs) for N_2O, distinguishing the effects of water management, crop type, and fertilizer management. These authors concluded that EFs are generally lower in Mediterranean cropping systems, mostly rainfed ones, than those used as tier 1 default EFs by IPCC, and that water regime (irrigation technique or precipitation amount) was the most important factor controlling the magnitude of soil N_2O EFs from Mediterranean regions. Application of these new EFs would lead to a much lower

http://dx.doi.org/10.1016/j.agee.2016.12.032

Please cite this article in press as: A. Sanz-Cobena, et al., Mitigation and quantification of greenhouse gas emissions in Mediterranean cropping systems, Agric. Ecosyst. Environ. (2017), http://dx.doi.org/10.1016/j.agee.2016.12.032

N_2O emission estimation at the country scale, as it is shown for the case of Spain (Cayuela et al., in this issue).

Five studies have provided original results from field work aiming to assess the effect of management practices on N_2O emissions. The papers by Abalos et al. (in this issue) and Hube et al. (in this issue) focus on the potential of nitrification inhibitors to abate N_2O emissions in contrasting environments and for different crops under Mediterranean climate. The former, using static chambers, examines the effect of rainfall variability on the effectiveness of the nitrification inhibitor DMPP (3,4-dimethyl pyrazole phosphate) to abate N_2O fluxes in a rain-fed barley crop in Central Spain; the authors conducted a three year study showing EFs to be lower than the IPCC default value, thus suggesting that Mediterranean-specific EFs should be used. They also conclude that nitrification inhibitors are effective in mitigating N_2O in semiarid Mediterranean environments, although the degree of mitigation depends on rainfall amount and distribution. The authors point out that, although in contrast to the traditional split application at planting and tillering, a single fertilizer application at tillering may provide a more effective management opportunity for N_2O mitigation.

Hube et al. (in this issue) also evaluated the effectiveness of nitrification inhibitors, DCD (Dicyandiamide) in an oat crop cultivated in a Chilean volcanic ash soil and fertilized with different rates of urea. They also tested the potential of the urease inhibitor NBPT (N-(n-butyl)thiophosphoric triamide) to abate N_2O and CH_4 fluxes. Similar to the findings of Abalos et al. (in this issue), EFs were lower than the IPCC default values, possibly due to specific physico-chemical characteristics of volcanic ash soils. The effects of inhibitors in abating N_2O emission were not statistically significant. Related to crop yield, only the use of NBPT significantly increased productivity and N use efficiency, while DCD reduced yield-scaled N_2O emissions.

The field study of Guardia et al. (in this issue) carried out in central Spain, evaluated different fertilization strategies based on application of pig manure (*i.e.* compost from the solid phase, liquid fraction of pig slurry (LFPS), with and without DMPP), and its interaction with irrigation system (sprinkler *vs.* drip) on GHG (N_2O, CH_4) and nitric oxide (NO) emissions, and maize yield, as opposed to the conventional use of synthetic N sources (namely urea). The authors observed that use of DMPP with LFPS was an effective practice to reduce N_2O and NO emissions (40 and 32% reduction, respectively, compared to LFPS alone), and was also associated with the highest rates of CH_4 oxidation. Moreover, the treatment that used only organic fertilizer led to similar yield-scaled N_2O emissions compared to urea. Regarding the irrigation system, drip irrigation was the most promising management practice to mitigate yield-scaled GHG emissions, though the side effects of increasing NO losses should be taken into account. This study showed that the use of organic fertilizers in irrigated maize is a suitable alternative for reducing GHG emissions without yield penalties in irrigated systems, but only if they are properly managed.

In a contrasting cropping system, Wolff et al. (in this issue) measured the mitigation effect of fertigation in an almond orchard of California (USA). These authors measured N_2O production in a soil profile showing that application of urea ammonium nitrate produced the highest N_2O emissions at 10–15 cm depth, while N_2O was reduced to N_2 below 20 cm in all treatments. High-frequency fertigation with ammoniacal fertilizers did not mitigate N_2O emissions, but nitrate-based fertilizers did, suggesting that nitrifier denitrification can be a major source of N_2O with ammoniacal fertilizers applied through fertigation.

Two papers presented modelling approaches to assess the effectiveness of agronomic practices for N_2O mitigation. On the one hand, Alvaro-Fuentes et al. (in this issue) used the Daycent model (Del Grosso et al., 2011) to predict N_2O emissions and to determine the impact of climate change and atmospheric CO_2 enrichment under different land uses (cropland, abandoned land and afforested land) in the Spanish Mediterranean region over an 85-year period. Model results showed that under climate change, water filled pore space (WFPS) could decrease (*i.e.* oxygenation increased) between 4% and 15%. The authors estimate that climate change would decrease soil N_2O emissions in a range of land uses.

In the other modelling paper, Plaza-Bonilla et al. (in this issue), using the soil and crop model STICS (Brisson et al., 2008), tested the effect of a Mediterranean precipitation gradient on mitigation of N_2O emissions under different management practices (*e.g.*, N fertilizer type, grain legume introduction in crop rotations and crop residues management). Results confirmed the importance of climatic conditions for N_2O emission and mitigation across an aridity gradient. The lower N_2O emissions at the driest sites were associated with lower fertilization rates, but also with other factors, particularly the drier water regime. Among the management practices evaluated, incorporation of winter pea in traditional cereal-based rotations reduced N_2O emissions the most.

3. Carbon sequestration

The study of C sequestration in Mediterranean cropping systems is of particular importance because the levels of OM in Mediterranean soils are generally low and are expected to decrease further (Davidson and Janssens, 2006). Management practices aimed at increasing soil organic C (SOC) stocks are therefore paramount. Five papers focus on the potential of different agricultural practices to enhance the SOC stocks in Mediterranean soils. Montanaro et al. (in this issue) evaluated the effect of so called sustainable management practices (zero-tillage, weed mowing, retention of above-ground residues and the import of organic amendments) on the C budget of an Italian peach orchard over a seven-year period. The field study revealed that these practices reduced the release of C *via* removal and storage of C in both soil and tree biomass, and increased the C stock at a mean rate 20 times higher than that of conventional practices, with associated benefits for soil structure and function (*e.g.* soil water holding capacity and biodiversity). Although both being sinks of C, the net ecosystem C balance of sustainably managed orchards was reported to be 8 times higher than that of conventionally managed ones.

The effect of reusing by-products or treated urban wastes on the GHG balance of these systems was also considered. Calleja-Cervantes et al. (in this issue) determined over 20 years the influence of continued yearly application of thermophilic digested sewage sludge at three different rates on soil C sequestration, as well as potential side effects in the form of other GHG emissions. Application rate was the most important factor in determining C and nutrient dynamics as well as crop response. The highest application rate of sludge (80 t ha^{-1}) led to the largest increase in soil organic C and N, as well as GHG emissions. This was also the only case where crop yield decreased, due to irreversible lodging (crops falling over). In contrast, a lower dose of sludge (40 t ha^{-1}), in combination with urea, increased soil microbial activity, which ultimately activates soil metabolism, and enhances C sequestration without increasing GHG emissions, in comparison with soils fertilized only with urea.

Following these two field studies, three modelling approaches complete the C sequestration section. The paper of Farina et al. (in this issue) reported a modelling study for soil C stocks and CO_2 emission changes over 20 years using the RothC-10N model (Coleman and Jenkinson, 1996) in a region of Southern Italy and across three agricultural land use types (arable land, pasture land, and permanent woody cropland), and also including actual

Please cite this article in press as: A. Sanz-Cobena, et al., Mitigation and quantification of greenhouse gas emissions in Mediterranean cropping systems, Agric. Ecosyst. Environ. (2017), http://dx.doi.org/10.1016/j.agee.2016.12.032

cropping sequences. In addition, using an interpolation method (EBK) to predict the modelled values in locations lacking initial information, the authors projected model outputs across a surface of ca. 7000 km^2. The spatial projection allowed identifying the potential of land use to sequester C, and evaluate the potential for different soil types and crop sequences. The proposed methodology can be applied to other regional studies. Following its validation with field data, Muñoz-Rojas et al. (in this issue) used the CarboSOIL model (Muñoz-Rojas et al., 2013) to analyze the SOC content under two irrigation and climate change scenarios, and under different land use types and soil depths, in the region of El Fayoum (Northern Egypt). Climate change scenarios suggested a general decrease of SOC content in the top soil layer, but an increase in deeper layers. Irrigated land would be particularly vulnerable to losses of soil organic C stocks. The importance of assessing SOC contents along the soil profiles is stressed. Finally, Pardo et al. (in this issue) evaluated the potential for climate change mitigation of introducing different practices for orchards and horticultural cropping, in a case study in the Mediterranean coastal area in Spain by running two models, RothC and SIM$_{\text{WASTE}}$. The evaluated measures included cover crops and the application of several types of exogenous inputs. Model results suggested a high potential for SOC accumulation in orchards and the intensive horticultural system by properly managing C inputs. Sowing cover crops in orchards could be a promising measure, also showing an important benefit for climate change adaptation.

4. Methane emissions

There is very little information on CH_4 fluxes from Mediterranean wetlands (Petrescu et al., 2015), with rice paddy fields being an anthropogenic wetland that produces high levels of CH_4 emissions. Most studies on GHG in rice paddy fields have taken place in Asia, where climatic and management conditions differ from those in Mediterranean systems. The study by Meijide et al. (in this issue) evaluated, for the first time, the effect of water management on GHG emissions in a Mediterranean rice paddy field. Carbon dioxide, N_2O and CH_4 fluxes were assessed using eddy covariance and chamber techniques during two consecutive years with different water management strategies. This study shows that mid-season drainage of the otherwise flooded field, has the potential to decrease net GHG emissions, mainly due to the decreased CH_4 fluxes and despite of increased N_2O emissions. Mid-season drainage also resulted in lower water losses through evapotranspiration, leading to water savings, which is highly beneficial in Mediterranean systems.

5. Concluding remarks

- 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 could be a 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, show a very high mitigation potential in Mediterranean cropping systems. This potential has been particularly highlighted for permanent crops, whereas 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.

Acknowledgements

The Editors of this special issue would like to acknowledge the authors of the manuscripts for their contributions, the reviewers for thorough revisions and the Editor in Chief, Prof. Juerg Fuhrer, Editor Dr. Surinder Saggar and managing editors Jia Yang for their advice during the editing process. Alberto Sanz-Cobena is grateful to the Spanish Ministry of Science and Innovation and the Autonomous Community of Madrid for their economic support through Projects AGL2012-37815-CO5-01, the Agrisost Project S2013/ABI-2717 as well as the FACCE JPI MACSUR project. We acknowledge the members of the Scientific Network on GHG mitigation from the agroforestry sector in Spain (REMEDIA) for helpful suggestions and comments on the special issue and for providing a space for discussion and science development.

References

Abalos, D., Sanz-Cobena, A., Andreu, G., Vallejo, A., 2016. Rainfall amount and distribution regulate DMPP effects on nitrous oxide emissions under semiarid Mediterranean conditions. Agric. Ecosyst. Environ. (in this issue).
Aguilera, E., 2016. The influence of management practices on the greenhouse gas balance of Mediterranean cropping systems. Identifying the climate change mitigation potential through quantitative review and life cycle assessment. Doctoral Thesis. Universidad Pablo de Olavide, Sevilla.
Aguilera, E., Lassaletta, L., Gattinger, A., Gimeno, B.S., 2013a. Managing soil carbon for climate change mitigation and adaptation in Mediterranean cropping systems: a meta-analysis. Agric. Ecosyst. Environ. 168, 25–36.
Aguilera, E., Lassaletta, L., Sanz-Cobena, A., Garnier, J., Vallejo, A., 2013b. The potential of organic fertilizers and water management to reduce N_2O emissions in Mediterranean climate cropping systems. Review. Agric. Ecosyst. Environ. 164, 32–52.
Aguilera, E., Guzmán, G.I., Alonso, A.M., 2015a. Greenhouse gas emissions from conventional and organic cropping systems in Spain: i. Herbaceous Crops Agron. Sustain. Dev. 35, 713–724.
Aguilera, E., Guzmán, G.I., Alonso, A.M., 2015b. Greenhouse gas emissions from conventional and organic cropping systems in Spain II. Fruit tree orchards. Agron. Sustain. Dev. 35, 725–737.
Alvaro-Fuentes, J., Arrue, J.L., Bielsa, A., Cantero-Martínez, C., Plaza-Bonila, D., Paustian, K., 2016. Simulating climate change and land use effects on soil nitrous oxide emissions in Mediterranean conditions using the Daycent model. Agric. Ecosyst. Environ. (in this issue).
Aschmann, H., 1973. Distribution and Peculiarity of Mediterranean Ecosystems, In: Mediterranean Type Ecosystems. Springer, pp. 11–19. doi:http://dx.doi.org/10.1007/978-3-642-65520-3_2.
Bindi, M., Olesen, J.E., 2011. The responses of agriculture in Europe to climate change. Reg. Environ. Change 11, S151–S158.
Biswas, W.K., Barton, L., Carter, D., 2008. Global warming potential of wheat production in Western Australia: a life cycle assessment. Water Environ. J. 22, 206–216.
Brisson, N., Launay, M., Mary, B., Beaudoin, N., 2008. Conceptual Basis, Formalisations and Parameterization of the STICS Crop Model. Editions QUAE, INRA, Versailles Cedex (78026).
Calleja-Cervantes, M.E., Aparicio-Tejo, P.M., Villadas, P.J., Irigoyen, I., Irañeta, J., Fernández-González, A.J., Fernández-López, M., Menéndez, S., 2016. Rational application of treated sewage sludge with urea increases GHG mitigation opportunities in Mediterranean soils. Agric. Ecosyst. Environ. (in this issue).
Cayuela, M.L., Aguilera, E., Sanz-Cobena, A., Adams, D.C., Abalos, D., Barton, L., Ryals, R., Silver, W.L., Alfaro, M.A., Pappa, V.A., Smith, P., Garnier, J., Billen, G., Bouwman, L., Bondeau, A., Lassaletta, L., 2016. Direct nitrous oxide emissions in Mediterranean climate cropping systems: emission factors based on a meta-analysis of available measurement data. Agric. Ecosyst. Environ. (in this issue).
Coleman, K., Jenkinson, D.S., 1996. RothC-26.3 ? A model for the turnover of carbon in soil. In: Powlson, D.S., Smith, P., Smith, J.U. (Eds.), Evaluation of Soil Organic Matter Models Using Existing Long-Term Datasets. NATO ASI Series I. Springer-Verlag, Heidelberg, pp. 237–246.
Davidson, E.A., Janssens, I.A., 2006. Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. Nature 440, 165–173. doi:http://dx.doi.org/10.1038/nature04514.
Del Grosso, S.J., Parton, W.J., Keough, C.A., Reyes-Fox, M., 2011. Special features of the DayCent modeling package and Additional Procedures for Parameterization,

Calibration, Validation, and applications. In: Ahuja, L., Ma, L. (Eds.), Methods of Introducing System Models into Agricultural Research. Advances in Agricultural Systems. Modeling Series 2, Madison Wisconsin, USA, pp. 155–176.

Diodato, N., Bellocchi, G., Romano, N., Chirico, G.B., 2011. How the aggressiveness of rainfalls in the Mediterranean lands is enhanced by climate change. Clim. Change 108, 591–599.

Farina, R., Marchetti, A., Francaviglia, R., Napoli, R., Di Bene, C., 2016. Modeling regional soil C stocks and CO_2 emissions under Mediterranean cropping systems and soil types. Agric. Ecosyst. Environ. (in this issue).

García-Ruiz, J.M., López-Moreno, J.I., Vicente-Serrano, S.M., Lasanta-Martínez, T., Beguería, S., 2011. Mediterranean water resources in a global change scenario. Earth Sci. Rev. 105, 121–139.

Guardia, G., Tellez-Rio, A., García-Marco, S., Martin-Lammerding, D., Tenorio, J.L., Ibáñez, M.A., Vallejo, A., 2016a. Effect of tillage and crop (cereal versus legume) on greenhouse gas emissions and Global Warming Potential in a non-irrigated Mediterranean field. Agric. Ecosyst. Environ. 221, 187–197.

Guardia, G., Cangani, M.T., Sanz-Cobena, A., Junior, J.L., Vallejo, A., 2016b. Management of pig manure to mitigate NO and yield-scaled N_2O emissions in an irrigated Mediterranean crop. Agric. Ecosyst. Environ. (in this issue).

Hube, S., Alfaro, M.A., Scheer, C., Brunk, C., Ramírez, L., Rowlings, D., Grace, P., 2016. Effect of nitrification and urease inhibitors on nitrous oxide and methane emissions from an oat crop in a volcanic ash soil. Agric. Ecosyst. Environ. (in this issue).

Iglesias, A., Garrote, L., Diz, A., Schlickenrieder, J., Martin-Carrasco, F., 2011. Re-thinking water policy priorities in the Mediterranean region in view of climate change. Environ. Sci. Policy 14, 744–757.

Klausmeyer, K.R., Shaw, M.R., 2009. Climate change, habitat loss, protected areas and the climate adaptation potential of species in mediterranean ecosystems worldwide. PLoS One 4.

Meijide, A., Gruening, C., Goded-Ballarin, I., Seufert, G., Cescatti, A., 2016. Water management reduces greenhouse gas emissions in a Mediterranean rice paddy field. Agric. Ecosyst. Environ. (in this issue).

Montanaro, G., Tuzio, A.C., Xylogiannis, E., Kolimenakis, A., Dichio, B., 2016. Carbon budget in a Mediterranean peach orchard under different management practices. Agric. Ecosyst. Environ. (in this issue).

Muñoz-Rojas, M., Abd-Elmabod, S.K., Zavala, L.M., De la Rosa, D., Jordan, A., 2013. Climate change impacts on soil organic carbon stocks of Mediterranean agricultural areas: a case study in Northern Egypt. Agric. Ecosyst. Environ. (in this issue).

Pardo, G., del Prado, A., Alvaro-Fuentes, A., Martínez-Mena, M., Rodríguez Martín, J. A., Bustamante, M.A., Moral, R., 2016. Intensive orchard and horticulture systems in Spanish Mediterranean coastal areas: is there a real possibility to contribute to C sequestration? Agric. Ecosyst. Environ. (in this issue).

Petrescu, A.M.R., Lohila, A., Tuovinen, J.-P., Baldocchi, D.D., Desai, A.R., Roulet, N.T., Vesala, T., Dolman, A.J., Oechel, W.C., Marcolla, B., Friborg, T., Rinne, J., Matthes, J. H., Merbold, L., Meijide, A., Kiely, G., Sottocornola, M., Sachs, T., Zona, D., Varlagin, A., Lai, D.Y.F., Veenendaal, E., Parmentier, F.-J.W., Skiba, U., Lund, M., Hensen, A., van Huissteden, J., Flanagan, L.B., Shurpali, N.J., Grünwald, T., Humphreys, E.R., Jackowicz-Korczyński, M., Aurela, M.A., Laurila, T.782, Grüning, C., Corradi, C.A.R., Schrier-Uijl, A.P., Christensen, T.R., Tamstorf, M.P., Mastepanov, M., Martikainen, P.J., Verma, S.B., Bernhofer, C., Cescatti, A., 2015. The uncertain climate footprint of wetlands under human pressure. Proc. Natl. Acad. Sci. 112, 4594–4599. doi:http://dx.doi.org/10.1073/pnas.1416267112.

Plaza-Bonilla, D., Léonard, J., Peyrard, C., Mary, B., Justes, E., 2016. Precipitation gradient and crop management affect N_2O emissions: simulation of mitigation strategies in rainfed Mediterranean conditions. Agric. Ecosyst. Environ. in this issue).

Sanz-Cobeña, A., Lassaletta, L., Aguilera, E., del Prado, A., Garnier, J., Billen, G., Iglesias, A., Sánchez, B., Guardia, G., Abalos, D., Plaza-Bonilla, D., Puigdueta, I., Moral, R., Galán, E., Arriaga, H., Merino, P., Infante-Amate, J., Meijide, A., Pardo, G., Alvaro-Fuentes, J., Gilsanz, C., Báez, D., Doltra, J., González-Ubierna, S., Cayuela, M.L., Menendez, S., Diaz-Pines, E., Le-Noe, J., Quemada, M., Estellés, F., Calvet, S., van Grinsven, H., Westhoek, H., Sanz, M.J., Sánchez-Jimeno, B., Vallejo, A., Smith, P., 2016. Strategies for GHG mitigation in Mediterranean cropping systems. Review. Agric. Ecosyst. Environ. (in this issue).

Trnka, M., Olesen, J.E., Kersebaum, K.C., SkjelvÅG, A.O., Eitzinger, J., Seguin, B., Peltonen-Sainio, P., RÖTter, R., Iglesias, A.N.A., Orlandini, S., DubrovskÝ, M., Hlavinka, P., Balek, J., Eckersten, H., Cloppet, E., Calanca, P., Gobin, A., VuČEtiĆ, V., Nejedlik, P., Kumar, S., Lalic, B., Mestre, A., Rossi, F., Kozyra, J., Alexandrov, V., SemerÁDovÁ, D., ŽAlud, Z., 2011. Agroclimatic conditions in Europe under climate change. Glob. Change Biol. 17, 2298–2318.

Venkat, K., 2012. Comparison of twelve organic and conventional farming systems: a life cycle greenhouse gas emissions perspective. J. Sustain. Agric. 36, 620–649.

Wolff, M.W., Hopmans, J.W., Stockert, C.M., Burger, M., Sanden, B.L., Smart, D.R., 2016. Effects of drip fertigation frequency and N-source on soil N_2O production in almonds. Agric. Ecosyst. Environ. (in this issue).

Wriedt, G., Van der Velde, M., Aloe, A., Bouraoui, F., 2009. Estimating irrigation water requirements in Europe. J. Hydrol. 373, 527–544.

Alberto Sanz-Cobena*
ETSI Agrónomos, Technical University of Madrid, Ciudad Universitaria, 28040 Madrid, Spain

Luis Lassaletta**
PBL Netherlands Environmental Assessment Agency, Bezuidenhoutseweg 30, 2594 AV Den Haag, The Netherlands

Josette Garnier
Sorbonne Universités, Univ Paris 06, CNRS, EPHE, UMR 7619 METIS, 4 place Jussieu, 75005 Paris, France

Pete Smith
Institute of Biological and Environmental Sciences, University of Aberdeen, 23 St Machar Drive, Aberdeen, AB24 3UU, UK

* Corresponding author.

** Corresponding author.
E-mail addresses: a.sanz@upm.es (A. Sanz-Cobena), lassalet@bio.ucm.es (L. Lassaletta).

Please cite this article in press as: A. Sanz-Cobena, et al., Mitigation and quantification of greenhouse gas emissions in Mediterranean cropping systems, Agric. Ecosyst. Environ. (2017), http://dx.doi.org/10.1016/j.agee.2016.12.032