Scenario analysis of alternative management options on the forage production and greenhouse gas emissions in Mediterranean grasslands

Pulina A., Bellocchi G., Seddaiu G., Roggero P.P.

in

Casasús I. (ed.), Lombardi G. (ed.).
Mountain pastures and livestock farming facing uncertainty: environmental, technical and socio-economic challenges

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 116

2016
pages 263-266

Scenario analysis of alternative management options on the forage production and greenhouse gas emissions in Mediterranean grasslands

A. Pulina[1,*], G. Bellocchi[2], G, Seddaiu[1] and P.P. Roggero[1]

[1]Dipartimento di Agraria & Nucleo Ricerca Desertificazione, University of Sassari, Sassari (Italy)
[2]UREP, INRA, 63000 Clermont-Ferrand (France)
*e-mail: anpulina@uniss.it

Abstract. Grazing businesses need to develop an understanding of their greenhouse gas (GHG) budget and be able to assess the impact of alternative management options. In this study annual emissions of the three main agricultural GHGs (CO_2, CH_4 and N_2O) were generated for contrasting management scenarios using 50-year simulations with a biogeochemical model in a sheep-grazing system of Northern Sardinia (Italy). Three stocking rates (0.21, 0.42 and 0.84 LSU ha^{-1} yr^{-1}) combined with three N fertilization rates (0, 100, 150 kg N ha^{-1} yr^{-1}) were assessed. CO_2 emissions showed higher sensitivity to interannual weather variability than CH_4 and N_2O emissions, with the system holding its sink capacity but with lower rate of sequestration in the most arid years. When N rates did not exceed 100 kg ha^{-1}, a trade-off can be identified between an adequate pasture production and relatively low GHG emissions. The analysis indicated that there is scope for grazing businesses to choose alternative management options to influence their GHG budget. Studies of this type are challenging for livestock industries and policy makers to work through.

Keywords. Forage production – Greenhouse gas (GHG) emissions – Management options – Mediterranean pastures – Simulation.

Analyse des scénarios des options alternatives de gestion des pâturages méditerranéennes sur la production de fourrage et les emissions de gas à effet serre

Résumé. *L'évaluation des bilans de gaz à effet de serre (GES) dans les systèmes prairiaux pâturés vise à quantifier les émissions liées à la gestion de ces mêmes systèmes. Dans cette étude, un modèle biogéochimique de simulation a été utilisé pour générer les émissions annuelles des trois principaux GES agricoles (CO_2, CH_4 et N_2O) d'un système prairial du nord de la Sardaigne (en Italie), pâturé par des moutons. Les valeurs de GES ont été estimées sur une période de 50 ans en simulant des scénarios contrastés de gestion. Trois taux de chargement animal (0,21, 0,42 et 0,84 UGB ha^{-1} an^{-1}) ont été évalués, combinés avec trois taux de fertilisation azotée (0, 100, 150 kg N ha^{-1} an^{-1}). Les émissions estimées de CO_2 ont montré une plus grande sensibilité à la variabilité météorologique interannuelle que les émissions de CH_4 et N_2O. Globalement, le système maintient sa capacité de séquestration bien que celle-ci soit plus faible dans les années les plus arides. Lorsque le taux d'azote ne dépasse pas les 100 kg ha^{-1}, la continuité de la production pastorale s'accompagne d'émissions de GES relativement faibles. L'analyse indique qu'il est possible, pour ce type de pâturages, d'opter pour des options alternatives de gestion influençant leur bilan de GES. Ces études posent des défis au secteur de l'élevage et fournissent des informations aux décideurs.*

Mots-clés. *Production fourragère – Émissions de gaz à effet de serre (GES) – Options de gestion – Pâturages méditerranéens – Simulation.*

I – Introduction

Mediterranean grasslands contribute to agricultural production and ecosystem services provision (EIP-AGRI, 2014). Their complex plant communities are characterized by the prevalence of therophytes annual species. The growing season typically starts in autumn with the germination of seedlings of annual species and ends in late spring (Caballero *et al.*, 2009). Pasture management practices contribute considerably to the relationships between different ecosystem functions such as forage and livestock productions, biodiversity and soil carbon sequestration. Scenarios analysing the impact of alternative management options on grassland functions may help identifying suitable practices and provide decision support tools to stakeholders. In this paper the results of a model-based simulation of the effects of contrasting management options on the forage production and greenhouse gas emissions in Mediterranean grasslands are reported.

II – Materials and methods

1. Study site

The study site is the Berchidda-Monti Long Term Observatory (NE Sardinia, Italy) (40° 49' N, 9° 18' E, 300 m a.s.l.). Mean annual rainfall is 632 mm, concentrated in autumn-winter period, and mean annual temperature is 14.2° C. Soil type is Typic Dystroxerept (Lagomarsino *et al.*, 2011). Grassland is the prevalent land use, including dairy sheep and beef cattle grazing systems (Caballero *et al.*, 2009).

2. Study Design

A simulation study was run with the Pasture Simulation model (PaSim, https://www1.clermont.inra.fr/urep/modeles/pasim.htm), as calibrated and validated for the study-area in a previous work (Pulina *et al*., 2015). Starting from actual management conditions, i.e. mean annual stocking rate equals to 0.42 livestock units (LSU) ha^{-1} yr^{-1} and no N fertilization, two management options (animal density, N fertilization rate) were assessed following a factorial approach by increasing/decreasing by 50% the animal density combined with introducing N fertilisation at two rates (100 and 150 kg N ha^{-1}), which resulted into nine management scenarios (Table 1). The decreasing animal density (-50%) was intended as a mitigation option, while the other options served the purpose of assessing if the management intensification would lead to increased emissions.

To assess the effect of interannual weather variability, the model was run on a sample of 50 years of daily weather data representative of local climate, as generated from the climate generator WXGEN (Nicks *et al.*, 1990).

Monthly and yearly means of temperature and precipitation were calculated to elaborate the De Martonne-Gottmann aridity index ($b \geq 0$, extreme aridity), based on De Martonne (1942).

PaSim was run in a multi-year simulation to generate daily values of ecosystem respiration (RECO) and gross primary production (GPP) and thus to calculate yearly budgets of net ecosystem CO_2 exchanges (NEE = RECO-GPP) as well as annual emissions of methane (CH_4) and nitrous oxide (N_2O). Maximum total biomass production (dry matter, DM) was also assessed, assuming that the peak of grass production occurs at mid-May, as observed from field data.

Results are illustrated for three contrasting years singled out from the simulated series: the most and the least arid year, and a year representing intermediate conditions.

Table 1. Management scenarios codes

Stocking rate (LSU ha^{-1} yr^{-1})	N fertilization (kg N ha^{-1} yr^{-1})		
	0 (actual N rate)	100 (high N rate)	150 (very high N rate)
0.21 (-50% stocking rate)	-50_0	-50_100	-50_150
0.42 (actual stocking rate)	Act_0	Act_100	Act_150
0.84 (+50% stocking rate)	+50_0	+50_100	+50_150

III – Results and discussion

Scores for the aridity index (*b*) ranged from 7.35 (arid) to 22.32 (sub-humid), with average value of 13.91 (arid). Arid conditions were observed in 60% of the simulated years, while semi-arid and sub-humid conditions were in 32% and 8% of the years, respectively.

Based on NEE estimates (Fig. 1A), the grassland system results in a C sink (NEE<0), similar to other Mediterranean grasslands (Xu and Baldocchi, 2004), with large interannual variability characterised by less pronounced sink capacity in arid years. The trajectory of the C sink tends to increase with higher N supply, ranging from -0.1 Mg C ha^{-1} yr^{-1} in Act_0 most arid year to -4.4 Mg C ha^{-1} yr^{-1} in 50_150 intermediate year. The C sink in the most humid year was lower than in the intermediate year, likely owing to a higher C consumption, particularly in soil, due to conditions (presence of water) favouring organic matter mineralization.

N_2O emissions are expected to increase with increased N rates, which are amplified with N fertilization higher than 100 kg N ha^{-1} yr^{-1} (Fig. 1B), in the range 0.0013-0.0151 Mg N-N_2O ha^{-1} yr^{-1}. A reduction in N emissions is observed as a consequence of a reduction in animal density. Clear differences in N_2O emission trends were not shown in contrasting years, suggesting that N-cycle processes are less dependent on aridity conditions.

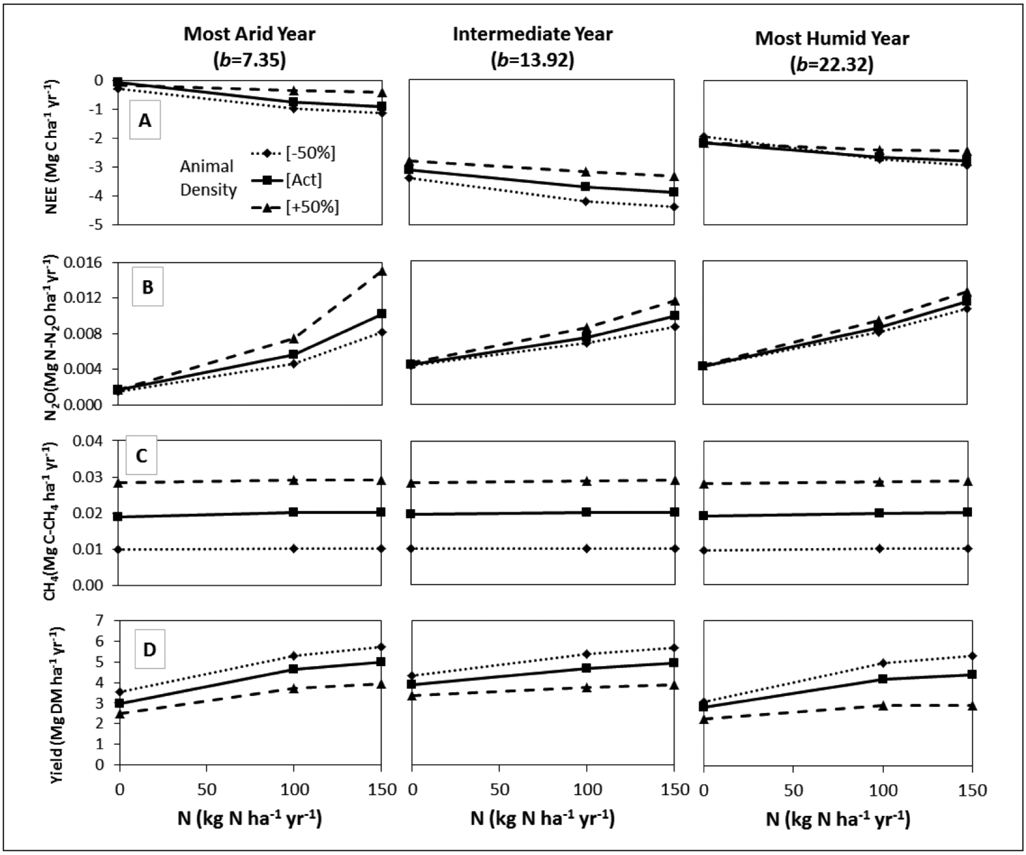

Fig. 1. Annual NEE (Mg C ha^{-1} yr^{-1}), N_2O emissions (Mg N-N_2O ha^{-1} yr^{-1}), CH_4 emissions (Mg C-CO_2 ha^{-1} yr^{-1}), and maximum biomass production (Mg DM ha^{-1} yr^{-1}) simulated by PaSim for alternative management scenarios (Table 1) and contrasting years.

CH_4 emissions are expected to increase/decrease by 40-50% with increasing/decreasing animal density by 50% (Fig. 1C). In contrasting years, neither N supply nor aridity conditions affected CH_4 emissions. Average values were 0.1, 0.2 and 0.3 Mg C-CH_4 ha^{-1} yr^{-1} for -50%, current and +50% stoking rate, respectively.

N supply supports biomass production, with less effect at rates higher than 100 kg ha^{-1} yr^{-1} (Fig. 1D).

IV – Conclusions

This simulation study indicates that GHG emissions from Mediterranean pastures may vary in relation to yearly rainfall patterns. As general conclusions:

(1) Decreasing density of grazing animals can be envisaged as an option to reduce emissions of CO_2, N_2O and CH_4.

(2) CO_2 emissions (NEE) are highly affected by interannual weather variability. Sardinian grassland sites are expected to reduce their sink capacity in dry years without becoming a C source.

(3) Increasing N fertilization can promote forage production with relatively limited impact on N_2O emissions if N rates do not exceed 100 kg ha^{-1}, which is rarely the case in current agricultural practice.

Acknowledgments

The results of this research were obtained within two international research projects named "FACCE MACSUR – Modelling European Agriculture with Climate Change for Food Security, a FACCE JPI knowledge hub" and "MAGGNET – Quantifying Greenhouse Gas Mitigation Effectiveness through the GRA Croplands Greenhouse Gas Network" and in the context of the Italian PASCUUM research project (L.R. 7/2007, Sardinia Region).

References

Caballero R., Fernández-González F., Perez Badia R., Molle G., Roggero P.P., Bagella S., D'Ottavio P., Papanastasis V.P., Fotiadis G., Sidiropoulou A. and Ispikoudis I., 2009. Grazing systems and biodiversity in Mediterranean areas: Spain, Italy and Greece. *Pastos,* 39, 9-152.

De Martonne E., 1942. Nouvelle carte mondiale de l'indice d'aridité. *Annales de Géographie,* 51, 242-250 (in French).

EIP-AGRI (Agricultural European Innovation Partnership), 2014. *Profitability of permanent grasslands.* Starting Paper. [online] [consulted in 02/2016] https://ec.europa.eu/eip/agriculture/sites/agri-eip/files/fg9_permanent_grassland_profitability_starting_paper_2014_en.pdf.

Lagomarsino A., Benedetti A., Marinari S., Pompili L., Moscatelli M.C., Roggero P.P., Lai R., Ledda L. and Grego S., 2011. Soil organic C variability and microbial functions in a Mediterranean agro-forest ecosystem. *Biology and Fertility of Soils,* 47, 283-291.

Nicks A.D., Richardson C.W. and Williams J.R., 1990. Evaluation of the EPIC model weather generator. In: *Sharpley AN, and Williams JR (Editors), Erosion/Productivity Impact Calculator,* 1. Model Documentation. USDA-ARS Technical Bulletin, 1768.

Pulina A., Lai R., Salis L., Piredda A., Becugna G., Seddaiu G., Roggero P.P. and Bellocchi G., 2015. Utilizzo del modello PaSim per la stima della produzione di biomassa e della respirazione del suolo in pascoli mediterranei. *XLIV Convegno Società Italiana di Agronomia*, Bologna, 14-16 settembre 2015 (in Italian).

Xu L. and Baldocchi D.D., 2004. Seasonal variation in carbon dioxide exchange over a Mediterranean grassland in California. *Agricultural and Forest Meteorology,* 1232, 79-96.