Modelling climate change impacts on production, carbon sequestration and water demand of livestock systems

Anne-Isabelle Graux, Romain Lardy, David Hill, Jean-François Soussana

Graux A.I.[(1)], Lardy R.[(1)], Hill D. [(2)], Soussana J.F.[(1)]
[(1)] INRA, UR874, UREP, Grassland Ecosystem Research, Clermont-Ferrand (France) aigraux@clermont.inra.fr
[(2)] ISIMA/LIMOS, UMR CNRS 6158, Université Blaise Pascal, Aubière (France)

Introduction

Although the increase of atmospheric CO_2 concentration is expected to enhance plant growth and to increase carbon sequestration in grassland ecosystems, an increase in future drought and heatwave events could turn grasslands into carbon sources, contributing to positive carbon-climate feedbacks, and could also lead to a decrease of yields, as it has already been observed in 2003. The aims of this work are: a) to simulate the impacts of climate change on production, carbon sequestration and water demand; b) to test the sustainability of contrasted grassland systems; c) to identify sources of uncertainty and of variability in climate projections.

Materials and Methods

To simulate the impacts of climate change on livestock systems, we used a biogeochemical grassland ecosystem “PASIM” [1] that simulates fluxes of carbon, nitrogen, water and energy at the soil-plant-animal-atmosphere interface (**Fig. 1**). We compared impact projections on production, carbon sequestration and water sensitivity of livestock systems, for a range of IPCC SRES scenarios (A1B, A2 & B1) of the ARPEGE model and of downscaling methods (anomalies, variable correction and statistical disagregation [2]) for the A1B scenario, at 2 French sites: Colmar and Toulouse (**Fig. 2**). To separate climate change and CO_2 concentration effects: i) the A1B scenario was simulated with a constant CO_2 concentration (325ppm) corresponding to 1970, ii) a constant climate control was simulated by sampling years between 1970 and 2000.

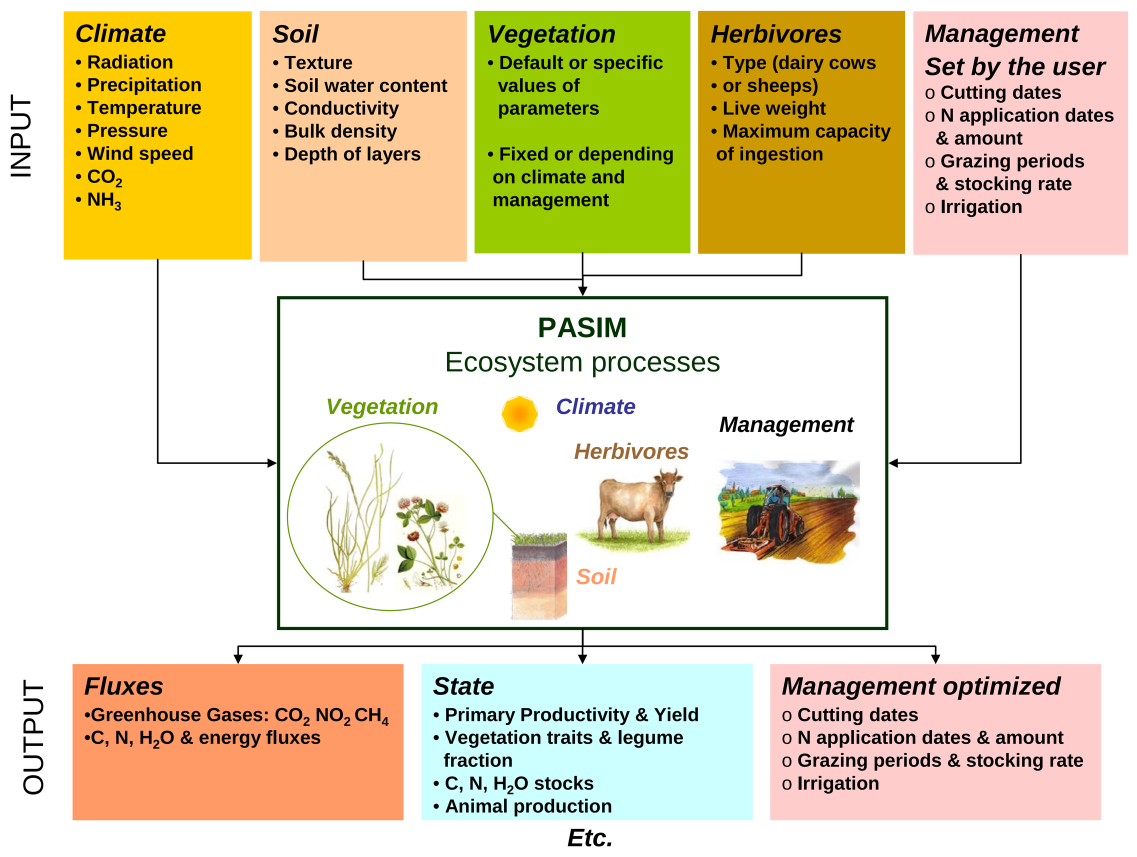
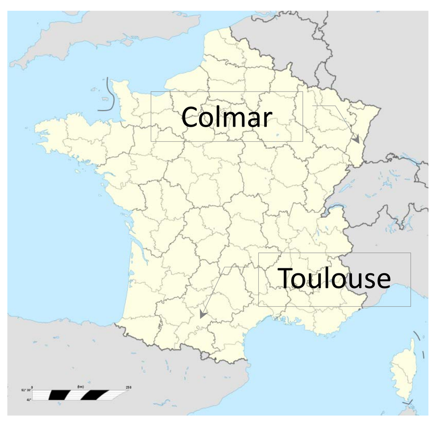


Figure 1 : The PASIM model



i)

FUTURE	SCENARIO	COLMAR T [°C]	COLMAR P [mm]	TOULOUSE T [°C]	TOULOUSE P [mm]
Near (2020-2050)	B1	+1.3	+ 2.7	+ 1.2	-48.2
	A1B	+ 1.4	+ 9.9	+ 1.5	-95.3
	A2	+ 1.1	+ 17.5	+ 1.2	-46.1
Far (2070-2100)	B1	+ 2.1	-17.3	+ 2.3	-167.7
	A1B	+ 3.3	-47.1	+ 3.4	-224.1
	A2	+ 4.2	-52.2	+ 4.5	-302.3

ii)

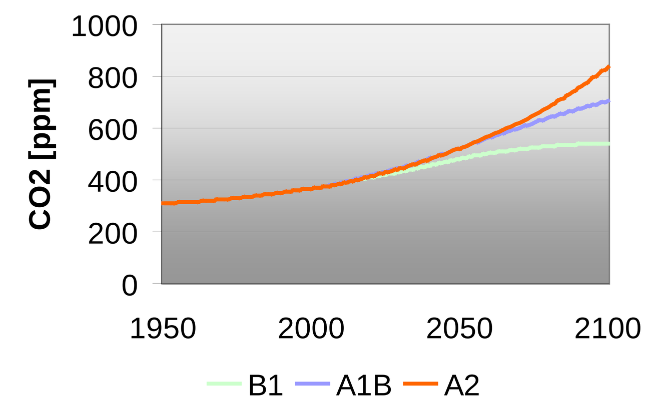


Figure 2 : Grassland sites for projections of impacts : a) location, b) evolutions of i) mean air temperature (T), ii) precipitations (P) and atmospheric CO_2 concentration

Name	Management	Grassland type	Fertilization [kg N.ha-1]	Irrigation [% of needs]	Cutting dates				Grazing periods		Stocking density [LSU.ha-1]
GI	Sown	100 % *Festuca aru.* or *Lolium per.*	320	80	15-apr.	30-jun.	15-aug.	15-oct	-	-	-
G			200	0	15-apr.	30-jun.	15-aug.	15-oct	-	-	-
PPP	Permanent	20% of *Trifolium rep.*	200	0	15-apr.	01-jun.	-	-	20/07-05/08	15/10-01/11	1,5
PPE		5% of *Trifolium rep.*	0	0	15-apr.	01-jun.	-	-	20/07-05/08	15/10-01/11	0,8

Figure 3 : Simulated livestock systems

Moreover, we compared 6 livestock systems, differing by grassland type (permanent or sown, grass species, legume fraction) and management (fertilization, irrigation, cutting and/or grazing) (**Fig. 3**). The agricultural practices were set at their current level. Soil organic matter was initialized at equilibrium with the climate in the 1950’s.

Results

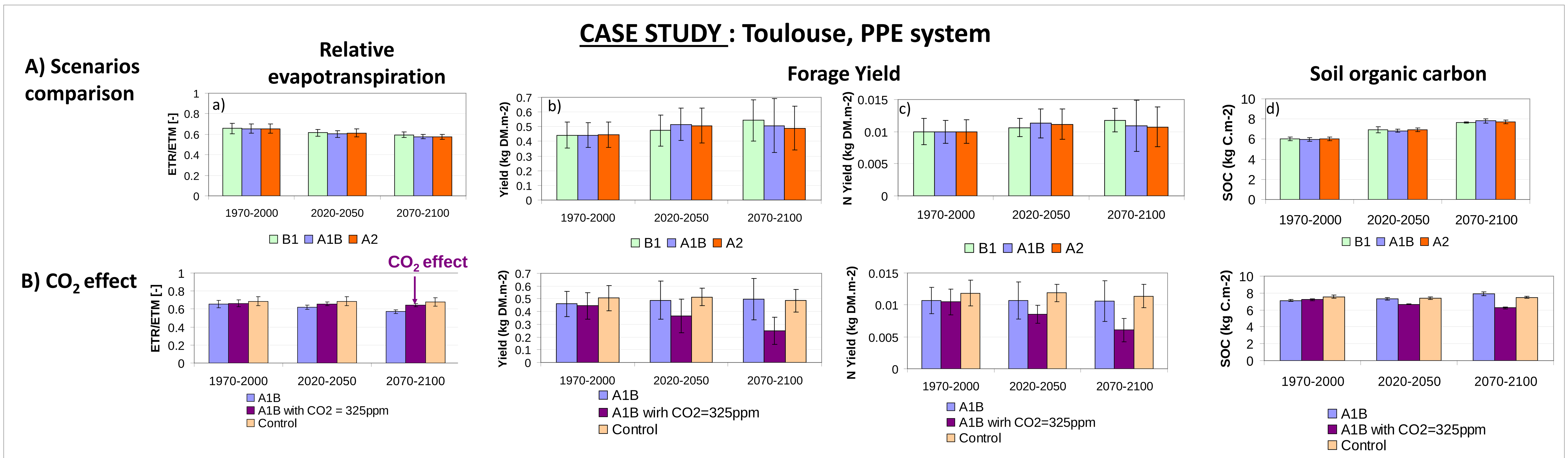


Figure 4: Projected climate change impacts of a) water stress, b) forage dry matter (DM) c) nitrogen yields and d) soil carbon at Toulouse for the “PPE system”, comparing 3 IPCC SRES scenarios climate scenarios obtained with the variable correction downscaling method (A), or separating the climate change and CO_2 concentration effects (B). Error bars show the interannual variability during the period

According to the PASIM model, when averaged over 30 years and compared to the reference period (1970-2000):

• Water requirements for grassland ecosystems tend to increase in far future, especially for the more pessimistic A2 scenario,

• Production does not vary significantly. Results emphasize a large effect of interannual climate variability for grassland production and there is no indication of a change in interannual yield variability,

• Soil organic carbon (SOC) content increases markedly through time, indicating that the increased atmospheric CO_2 concentration combined with warming leads to carbon sequestration.

These evolutions are observed for the 2 sites and the different livestock systems, with differences in mean values.

The separation of climate change and CO_2 concentration effects underlines the high weight of atmospheric CO_2 increase on PASIM results.

Conclusions

These results should be taken with caution, in regard to current model limitations for simulations of high temperatures and of severe droughts. Model tests and parametrisation against data from climate change experiments are planned and should allow more realistic projections of climate change impacts. Simulations at 10 other French sites are also planned and will complete these first results.

[1] Riedo et al. 1998, Vuichard et al. 2007, [2] Boé et al., 2006