Vulnerability of grassland systems to climate change and extreme events: a case study from the Central Massif of France.

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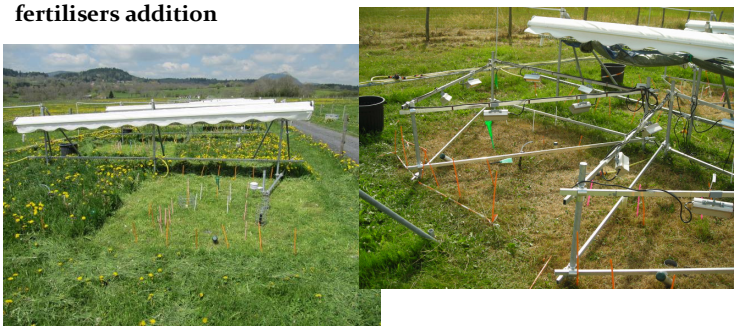
The project VALIDATE (French National Research Agency, 2008-2011)

- VALIDATE: Vulnerability of grasslands and livestock to climatic changes and extreme events in France and Europe (http://www1.clermont.inra.fr/validate)
- Objectives:
  - To represent the variability in temperature and precipitation via regionalized climate scenarios
  - To determine experimentally the impacts of extreme events (soil drought, heat waves) in interaction with an average climate change
  - To model impacts, adaptations and vulnerability at plot, farm and regional scales

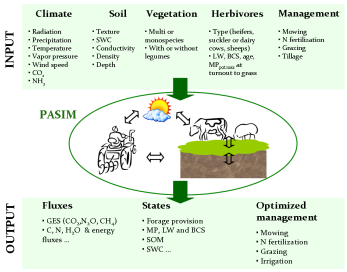
The same objectives are shared by the EU project CARBO-Extreme (http://www.carbo-extreme.eu)

Experimental setup

- **En experiment was set up with a permanent grassland in the upland central France (Massif Central, Theix, 45° 43' North, 03° 01' East, 890 m a.s.l.), conducted under actual and altered climatic conditions (warmer and drier), and managed intensively (f, six cuts per year) or extensively (i, three cuts per year) without fertilisers addition**



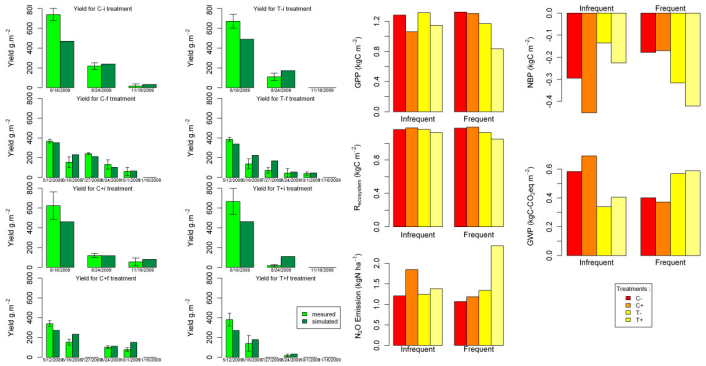
- For 2009, the **Pasture Simulation Model** (PASIM) was calibrated against vegetation (dry matter yield) and soil (temperature, moisture, organic matter) variables and employed to generate a variety of outputs related to carbon and nitrogen fluxes (CO2 and N2O emissions, gross and net productivity) and **global warming potential** under four climatic conditions:



- Actual climate (C-): 240.5 mm (summer rain), 768.8 mm (annual rain)
- Actual climate with summer extreme event (C+): heat wave (active warming system) and precipitation reduction (162 mm, 693.8 mm)
- Future climate (T-) corresponding to a projection of SRES A2 scenario for 2020-2049: night temperature increase (passive warming system) and precipitation reduction (146.0 mm, 564.8 mm)
- Future climate with summer extreme event (T+): active warming system to mimic extreme event under projected scenario (71 mm, 491.3 mm)

First-year results

- The following annual outputs are shown:
  - Estimated and observed dry matter yield (g m^{-2})
  - Gross primary production (GPP, kg C m^{-2})
  - Ecosystem respiration ($R_{ecosystem}$, kg C m^{-2})
  - Net biome productivity (NBP, kg C m^{-2})
  - Nitrous oxyde (N_2O) emissions (kg N ha^{-1})
  - Attributed global warming potential (GWP, kg CO2-C eq m^{-2}) to the plot, based on greenhouse gas fluxes (CO_2, N_2O, and CH_4) at plot + barn (dairy cows fed by harvested forage)



For 2009

- The simulated yield compared well to the observations, reflecting the within-year dynamic of grassland production under different managements and treatments
- Extreme events tend to reduce the GPP, while $R_{ecosystem}$ is substantially similar across treatments and managements (differences are apparent when considering individual components of respiration, e.g., root respiration tends to decrease whereas organic matter respiration to increase when extremes are applied)
- N_2O emissions indicate an increase when moving towards extreme conditions, especially when the system is intensively mown
- For the NBP, simulations show increased carbon (C) losses with extreme events: extensively-managed grasslands appear sensitive to extreme events occurring under today's conditions, while under future climate C losses are reduced; intensively-managed grasslands appear more adapted to current conditions but may lose more C in the future
- All treatments and managements contribute to the warming effect, with GWP largely reflecting the NBP and yield dynamics

General conclusions

- Grassland practices may determine the incidence of the impacts associated with extreme events and/or warming:
  - Climate extremes tend to have major impacts (C losses, positive GWP) on extensively-managed systems (--), which may be mitigated by a warming climate (+)
  - On intensively-managed grasslands, some adverse impacts are likely from extreme events (- / ≈) occurring in a changing climate (--)

Climate	Grassland management	
	Extensive	Intensive
Warming	+	--
Extremes	--	- / ≈

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