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Projecting yield and nutritive value of an alfalfa-timothy mixture under climate change

Marie-Noëlle Thivierge[1], Guillaume Jégo[1], Gilles Bélanger[1], Annick Bertrand[1], Gaëtan F. Tremblay[1], C. Alan Rotz[2], Budong Qian[1]

[1]Agriculture and Agri-Food Canada, Quebec and Ottawa Research Centers, Canada
[2] USDA Agricultural Research Service, University Park, PA, USA

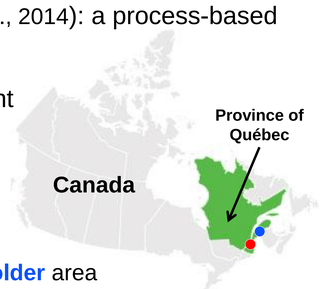
Introduction

Studies of climate change effects on forage crops have focused on individual forage species even though legume-grass mixtures are predominant on dairy farms in northern areas of North America.

Our objective was to assess the effect of future climate change and elevated CO_2 concentration on yield and nutritive value of **alfalfa** (*Medicago sativa* L.) and **timothy** (*Phleum pratense* L.), grown in a **mixture**, with or without the implementation of an **adaptation strategy** (modified harvest schedule including additional cuts).

Materials and methods

- The Integrated Farm System Model (IFSM; Rotz et al., 2014): a process-based farm model
- Model calibrated for timothy and alfalfa under current climate conditions in Canada (Jégo et al., 2015)
- Simulation of growth of an alfalfa-timothy mixture on dairy farms in eastern Canada:
  - ➢ for two contrasting climate areas : a **warmer** and a **colder** area
  - ➢ with two representative concentration pathways of greenhouse gas: RCP **4.5** and **8.5**
  - ➢ for three periods: reference (**ref.**), near future (**NF**), and distant future (**DF**)



- A 300-yr series of synthetic daily weather data was generated for each scenario using AAFC-WG, a stochastic weather generator (Hayhoe, 2000; Qian et al., 2004)

Projected changes in [CO_2] and climate conditions relative to the reference period in two contrasting climate areas in the province of Québec (for the growing season, 1 Apr. to 31 Oct.)

	• Warmer area	• Colder area
Reference (ref., 1971 to 2000) [Average temperature (°C), cumulated growing degree-days (GDD above 5°C, °C-d), and cumulated precipitation (mm)]	346 ppm CO_2 14.0°C 2008°C-d 625 mm	346 ppm CO_2 10.7°C 1393°C-d 552 mm
Scenarios	**NF 4.5**	**NF 8.5**	**NF 4.5**	**NF 8.5**
Near future (NF, 2020 to 2049) (Differences with reference period)	+101 ppm CO_2 +2.3°C +438°C-d +49 mm	+123 ppm CO_2 +2.4°C +475°C-d +55 mm	+101 ppm CO_2 +2.2°C +387°C-d +61 mm	+123 ppm CO_2 +2.4°C +426°C-d +43 mm
Scenarios	**DF 4.5**	**DF 8.5**	**DF 4.5**	**DF 8.5**
Distant future (DF, 2050 to 2079) (Differences with reference period)	+168 ppm CO_2 +3.6°C +699°C-d +39 mm	+293 ppm CO_2 +5.1°C +1029°C-d +41 mm	+168 ppm CO_2 +3.4°C +618°C-d +59 mm	+293 ppm CO_2 +5.0°C +939°C-d +72 mm

- Forage mixture yield and nutritive value were projected:

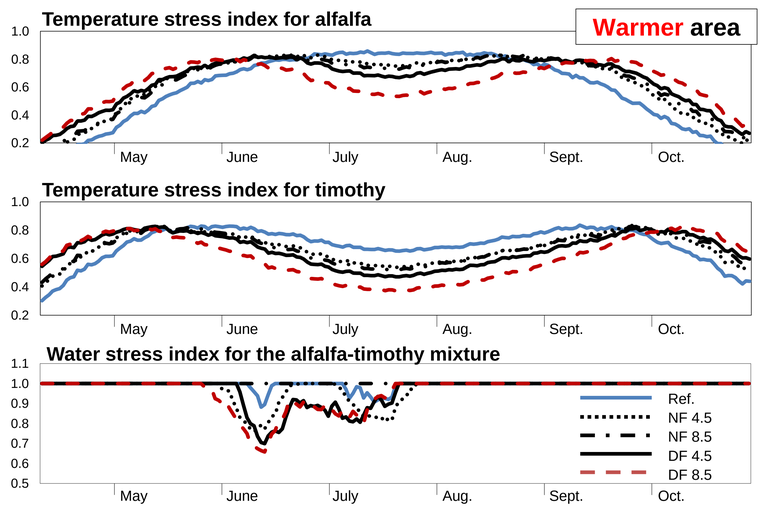
Without adaptation	**With adaptation**
- Same number and dates of harvest as the reference for all scenarios	- Harvest dates based on GDD criteria: ➢ 450°C-d (5°C basis) before 1st cut ➢ 520°C-d between cuts ➢ ≥ 500°C-d after last cut - 1 or 2 additional harvests

Results and discussion

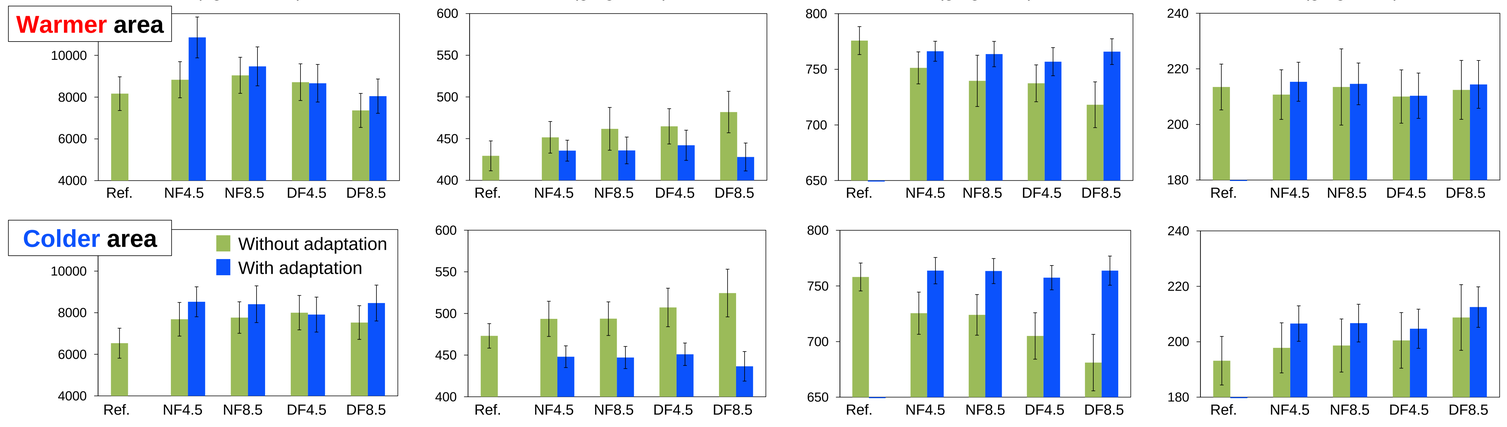
Temperature and water stress indices

- ➢ In both areas, temperature and water stresses are expected to increase in the future, mostly for timothy.
- ➢ Yield of forage summer regrowth is expected to decrease due to temperature and water stresses.

Temperature stress index (0 to 1.0)	**Value**
Optimum photosynthesis temperature (20°C alfalfa; 13.5°C timothy)	1.0 (no stress)
Below min. photosynthesis temp. (5°C alfalfa; 0°C timothy) or above max. photosynthesis temp. (35°C)	0 (max. stress)
Water stress index (0 to 1.0)	**Value**
Plant available water = 100% of critical soil moisture content	1.0 (no stress)
Plant available water = 0% of critical soil moisture content	0 (max. stress)



Projected dry matter (DM) yield and nutritive value of the alfalfa-timothy mixture



- ➢ **Without adaptation** Green bars
  - Annual DM yield is expected to increase (+7 to +22%) because of an increase in the first cut yield, except for the more drastic scenario in the warmer area (DF 8.5, -10%).
  - Concentration of the total digestible nutrients in the forage mixture is expected to decrease (-3 to -10%) because of higher GDD accumulation between cuts.
- ➢ **With adaptation** Blue bars
  - Annual DM yield is expected to increase in both areas (+6 to +33%), mostly because of additional cuts, and to remain unchanged in scenario DF 8.5 in the warmer area.
  - No decrease in the total digestible nutrients concentration is expected, due to the increased proportion of alfalfa in the mixture.
- ➢ **Next steps**: farm level analysis of the impact of climate change and evaluation of other forage mixtures.

Acknowledgements

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References

Jégo et al., 2015. Can. J. Plant Sci. 95:745–757. **Hayhoe**, 2000. Clim. Res. 14:75–87. **Qian et al.**, 2004. Clim. Res. 26:175–191. **Rotz et al.**, 2014. The integrated farm system model, reference manual version 4.1. In. Agricultural Research Service, United States Department of Agriculture.

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