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Modelling European Agriculture with Climate Change for Food Security
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Modelling responses of forages to climate change with a focus on nutritive value

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Nutritive value of forage is key factor affecting

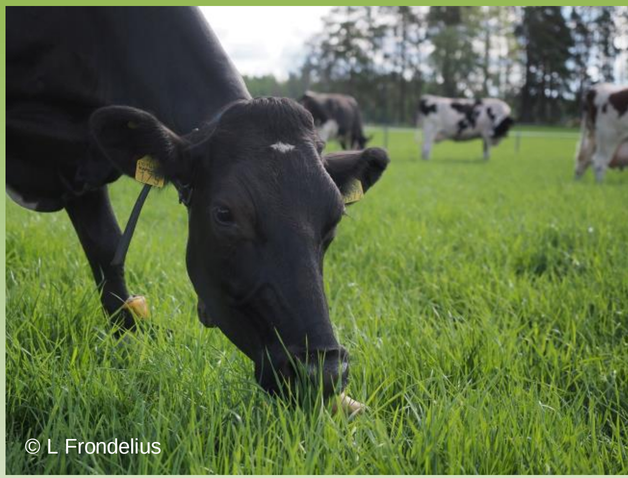
- ruminant nutrition
- animal performance
- need for other feeds
- productivity of the system
- quality of final products
- environmental impact of production

Climate change is expected to affect the nutritive value of grasslands by

- affecting plant physiological processes
- via effects on species composition.

Kipling et al 2016. Modeling European ruminant production systems: Facing the challenges of climate change. Agricultural Systems 147: 24–37

Variability in the grassland based systems



Frequency of defoliation, nutrient cycling

Monoculture

Binary mixture

Multispecies

Variables used to describe the nutritive value (NV) of forage grass based feeds

Energy variables

ME: metabolizable energy
NEL: net energy of lactation
NEM: net energy of maintenance
FME: fermentable metabolisable energy
FEm: feed unit for milk production (Norwegian)
…

Digestibility variables

CWD: cell wall digestibility
CWC: cell wall content/concentration
IVCWD: in vitro cell wall digestibility
NDF: neutral detergent fiber
NDS: neutral detergent solubles
dNDF: in vitro digestibility of NDF
iNDF: indigestible NDF
pdNDF: potentially digestible NDF
OMD: organic matter digestibility
DOM: digestible organic matter
IVOMD: in vitro organic matter digestibility
IVTD: in vitro true digestibility of dry matter
TDN: total digestible nutrients
D-value: concentration of digestible organic matter in DM
...

Protein variables

N concentration
CP: crude protein
DCP: digestible crude protein
RDP: rumen digestible protein
ERDP: effective rumen degradable protein
ADIP: acid detergent insoluble protein
DUP: digestible undegradable protein content
ADIN: acid-detergent insoluble nitrogen
...

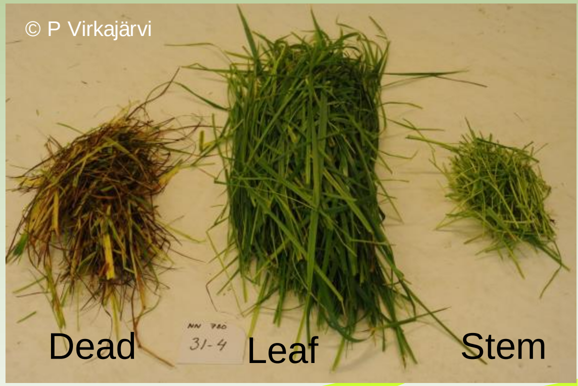
McDonald et al 2002. Animal Nutrition.

- Dissimilar feeding systems

- Most important are:
  - energy value
  - protein content

Factors and processes behind NV to be modelled

- Botanical composition
  - Grass - legumes- dicots
    - Grass functional traits
- Tiller dynamics & phenological stage
  - senescence
- Leaf to stem ratio
- Proportion of cell wall
- Chemical composition
  - Lignification of cell walls
  - in general (N, minerals etc.)



The aim

- To review the extent to which current process-based grass growth models are capable of characterising the nutritive value of forage grasses in relation to the projected climate change.

- To identificate of modelling approaches, the key characteristics of the forages and the production systems the individual models are developed for

The models

- Including process based growth models (PBMs) of temperate climate
- Reviewed from literature
- A questionnaire survey was sent to MACSUR knowledge hub partners

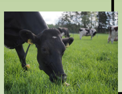
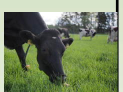
Results

- 8 PBMs simulating forage NV were included in the study
  - 6 from Europe
  - 2 from USA and Canada
- Developed mainly for silage - 2 models includes grazing
- Both generic and species specific models

The models

Acronym	Name	Developer/owner	First version (year)
BASGRA	BASic GRAss model	Centre for Ecology and Hydrology, UK; Norwegian Institute of Bioeconomy Research , Norway	2016
CATIMO	Canadian Timothy Model	Natural Resources Institute Finland (Luke)	2002
IFSM	Integrated Farm System Model	US Department of Agriculture, Agricultural Research Service (USDA ARS, USA)	2005 (first reference)
MCPy	Modèlisation de la Croissance des prairies	Centre Wallon de Recherches agronomiques	2001
PaSim	Pasture Simulation model	French National Institute for Agricultural Research (INRA)	1998 (full description)
Qual	Integrated Dynamic Model	Swedish University of Agricultural Sciences	1994
SPACSYS	Soil Plant and Atmosphere Continuum SYStem	Scottish Agricultural College and Rothamsted Research, UK	2007 (first reference)
STICS	Simulateur mulTIdisciplinaire pour les Cultures Standards	Institut National de la Recherche Agronomique (INRA, France)	1998

The main variables used to describe the NV of forages

			Energy variables		Digestibility variables		CP variables	
Model	Reference	Monoculture/ Mixture	ME	other	NDF	other	[N]	other
BASGRA	(Höglind *et al*. 2016)	Monoculture	-	-	-	-	Yes	CP
CATIMO	(Bonesmo and Bélanger, 2002)	Monoculture	-	-	Yes	IVTD, dNDF	Yes	RNC
 IFSM	(Rotz *et al*., 2015)	Mixture	Yes	NEL/ NEM	Yes	TDN	Yes	CP
MCPy	(Stilmant *et al*., 2001)	Mixture	-	VEM	Yes	-	-	-
 PaSim	(Graux *et al*., 2011)	Mixture	MEI	NELh	Yes	OMD, dNDF	Yes	-
QUAL	(Gustavsson *et al*., 1995)	Monoculture	Yes	-	-	OMD, IVTD	Yes	CP
SPACSYS	(Wu *et al*., 2007)	Mixture	-	-	-	-	Yes	-
STICS	(Brisson et al., 1998;Jégo *et al*., 2013) for NV	Mixture	-	-	Yes	IVTD, dNDF	Yes	CP

CP, crude protein; dNDF, in vitro digestibility of NDF; IVTD, in vitro true digestibility of dry matter; ME, metabolizable energy; MEI, metabolizable energy intake; [N], nitrogen concentration of forage; NDF, neutral detergent fiber; NEL, net energy of lactation; NELh, net energy content of the ingested herbage; NEM, net energy of maintenance; OMD, organic matter digestibility; RNC, relative nitrogen concentration; TDN, total digestible nutrients, VEM, available energy for milk production.

Discussion (1)

- PBMs tend to be fairly comprehensive in their consideration of weather variables that are expected to change
  - Limitation in CO_2 effect on water use efficiency, sugars, N, etc.
- Variables describing NV are clearly the most essential ones
  - DM of OM digestibility,
  - NDF, NDF digestibility
  - CP,
- Variables are very useful for feed planning.

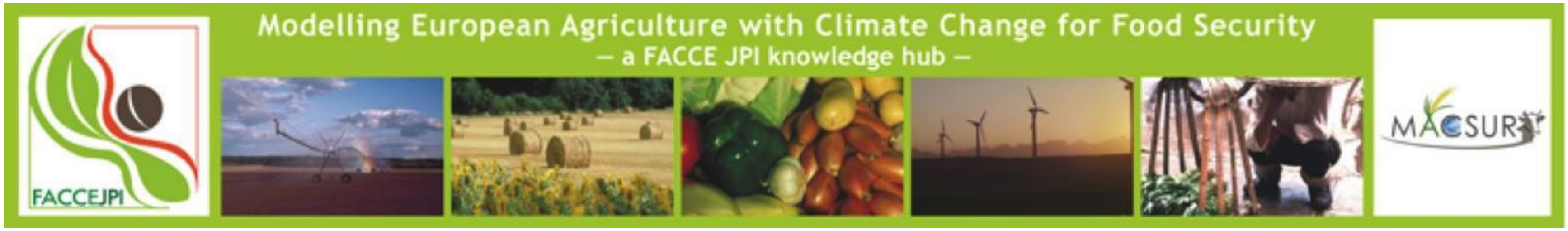
Discussion (2) - improvements
How to simulate:

1. physiological adaptation of the plants to changes in environmental conditions
2. formation and senescence of tillers
3. the dynamics of leaf chemical composition including water soluble carbohydrates
4. the response of C and N allocation to environmental change
5. quantify the relative importance of grazing regime and harvest dates
6. use information from field and laboratory trials with different genotypes to parameterize alternative cultivars, e.g. to represent developmental stages
7. improve the link between plant and soil water and soil N

Conclusions

- This work is the first step towards gathering and clarifying information about the possibilities of modelling NV
- The number of PBMs capable to predict NV is rather limited
- PBMs tend to be fairly comprehensive in their consideration of weather variables - reaction and acclimation to CO_2 level rise
- Development needed to reduce uncertainties
- a strong need for data including frequent time series of forage NV from experiments mimicking global change conditions
  - sharing of existing data sets

THANKS!



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