Dynamilk: a farming system model to explore the trade-offs between pasture, forage and milk production in grass-based systems

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Introduction:

Studied systems: dairy farming system based on grasslands located in mountain areas

- Geographical, soil and weather condition constraints
- Grassland based system
- More sensitive to climatic change

Possible plan of actions: Reinforce grassland utilization

- Dairy cattle management and strategies to optimize dairy cattle breeding
- Increasing the weight of grazing within the feeding system

Research hypothesis:

Dairy cattle need dynamics match Herbage supply dynamics

Improving the trade-offs and the robustness of the production system
Model description:

**Inputs**
- Paddocks characteristics
- Weather data
- Decision parameters (goals & steering)
- Dairy Cattle characteristics

**DYNAMILK**

- **Decision Sub model**
  - Strategy
  - Practice steering

- **Ressources Sub model**
  - Forage storage
  - Grasslands

- **Dairy cattle Sub model**
  - Batches of animals

**Outputs**
- Biomass
- Digestibility
- Yields
- Forage & grazing calendar
- Yearly assessment of forage resources
- Milk production
- Intake
- Energy balance

**Daily time step**
- Interactions between resources utilization and animals

**Milk responses to grass-based diet variations**

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**Introduction**  |  **Model description**  |  **Simulations : presentation & results**  |  **Conclusions**
Simulations:

Hyp : a better match between animal needs and herbage offer

2 contrasted systems based on different dynamics of animal needs
(one produces milk based on forages, WINTER,
the other produces milk on grass, SPRING)

« classical » System
Autumn & winter calving
“WINTER”

Effect of climatic variations 1995-2011

System
Spring calving
“SPRING”

Main variables to analyze system performances:

- Milk yield
- Forage self-sufficiency (selling – purchases + Δ storage )/ LU
- Annual herbage yields and energy values of different kind of forages
- Annual biomass utilization rate of grasslands (on paddock grazed by dairy cows)
Simulations:

Scenario and systems presentation:

- « classical » System
  - Autumn & winter calving
  - WINTER

- System
  - Spring calving
  - SPRING

Data based on farm survey data – Massif Central (France) (Jacquot et al., 2010)

Field pattern:

- Grasslands dominated by permanent pastures and productive grasses (Baumont et al., 2011)

Farm area ≈ 80 ha:
- 48% 1st cut, 17% grazing for dairy cows
- and 35% grazing for other batches

Dairy cattle:
- 51 dairy cows
- 31% replacement rate
- 7000 kg/cow/year (potential yield)
- 1200 kg/cow/year feed concentrates
- Age at the first calving: 3 year-old

Decrease of first cut area in order to increase dairy cow grazings

≈ 80 ha:
- 39% 1st cut, 26% grazing for dairy cows
- and 35% grazing for other batches

0,94 LU/ha

Simulations: presentation & results
**Simulation results:**

### Performance evolution between 1995 and 2011:

<table>
<thead>
<tr>
<th></th>
<th>“WINTER”</th>
<th>“SPRING”</th>
<th>ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forage self-sufficiency (t DM/LU)</td>
<td>0.52 ± 0.51</td>
<td>0.34 ± 0.37</td>
<td>-</td>
</tr>
<tr>
<td>Purchased forage (t DM)</td>
<td>0 ± 0</td>
<td>1.1 ± 0.25</td>
<td>NS</td>
</tr>
<tr>
<td>Milk yield (kg/cow/year)</td>
<td><strong>6 600 ± 78</strong></td>
<td><strong>6 759 ± 56</strong></td>
<td>0.006</td>
</tr>
</tbody>
</table>

**Self-sufficient systems for forages**

Δ (aMP – pMP) bigger for “WINTER” system than “SPRING”

(“WINTER” : -1.47 / “SPRING” : -1.16 kg/cow/d)

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Simulation results:

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- “SPRING”: a better stability of annual milk yields
- “WINTER”: sensitive to forage quality

Correlations btw MP and digestibility:
“Winter”: 0.47
“Spring”: 0.00

Simulations: presentation & results
Simulation results:

Effect of a climatic event on milk performances:

Season: Spring system is more sensitive to a spring draught

\[ \Delta(MP-pMP) \]

\[ \Delta \text{winter} = -2.39 \]
\[ \Delta \text{spring} = -3.76 \]

Year: Still, spring system is closer to its pMP

\[ \Delta(MP-pMP) \]

\[ \Delta \text{winter} = -2.03 \]
\[ \Delta \text{spring} = -1.08 \]
Conclusions:

Simulations:

✓ At a low stocking rate (0.94 LU/ha) and with productive grasslands, both systems are self-sufficient.

✓ Spring system seems to be more resilient to climatic changes.

⇒ a better match between animal needs and grass offer could be a relevant way to improve self-sufficiency through a better use of grass at grazing.

Dynamilk, a useful working tool to

Simulate interactions between grass resource dynamic and their utilization by dairy cattle

- Better understand system functioning and its performances
- Analyze system evolutions on different times-steps (year, season and day)
- Better understand climatic events and/or effects of production changes on farming system

⇒ concentrate decrease on system performances
⇒ stocking density increase on system performance
Thanks for your attention, please feel free to ask for more details!

A special thank to all persons who contributed to Dynamilk
Simulation results:

Increase of stocking density: 0.94 LU/ha (1.14 → 1.34 → 1.54)

- Stable milk yields
  - AC: +46 kg cow\(^{-1}\) y\(^{-1}\)
  - SC: +109 kg cow\(^{-1}\) y\(^{-1}\)

- Better utilization of grass offer
- Better quality of ingested grass

- Breakdown of forage self-sufficiency
  BUT balanced system until 62 cows for 81 ha
Simulation results:

Decrease of feed concentrates: 1200 kg/cow/year (800 → 400 → 0)

- Non-linear relationship
- kg of milk in less by kg of spare concentrates
  - AC: 0.90 to 1.17 kg milk/kg conc
  - SC: 0.83 to 1.05 kg milk/kg conc

- A slight increase of grass utilization (+3% for AC, +2% SC)

- Forage self-sufficiency still positive

Milk yield (kg.cow⁻¹.y⁻¹)

Biomass utilization rate

Forage self-sufficiency (t DM.LU⁻¹)
Simulation results:

Rapport entre la dmo et la Plprod annuelle:

Correlation entre dmo et Plprod:

|     | GA : 0.47 | GP : 0.0 |

Moyenne réalisée sur les données de 1995-2011
1\text{st} \text{cut (silage)}: \\
3.7 \text{ tDM/ha (0.80 UFL)} \\

1\text{st} \text{cut (field-dried hay):} \\
3.5 \text{ tDM/ha (0.69 UFL)} \\

Grazing: \\
“Winter” (13.7 kgDM/cow/day, 0.84 UFL) \\
“Spring” (15.0 kgDM/cow/day, 0.83 UFL)
Results: validation of Dynamilk

Forage system: cuts

Surface (ha) 05/10 06/01 06/15 07/01 07/15 08/01 08/15 09/01 10/01 10/15

Field-dried hay

Grass silage/haylage

Regrowth hay

Pastures only grazed by lactating cows

DYNAMILK
Grass silage: 3.7 tDM.ha-1 (3 - 4.4)
Field-dried hay: 3.5 tDM.ha-1 (2.3 - 4.7)
Regrowth hay: 1.5 tDM.ha-1 (0.7 - 2)

CASE STUDY
Grass silage: 3.6 tDM.ha-1
Field-dried hay: 4 tDM.ha-1
Regrowth hay: 2.5 tDM.ha-1

Same order of magnitude but slight differences for late cuts
⇒ Grass growth model is sensitive to dry periods

Introduction  Model description  Results: validation of model  Conclusions
Results: validation of Dynamilk

Forage system: forage quality

DYNAMILK
Grass silage: 0.80 g.g\(^{-1}\) (0.76 – 0.83)
Field-dried hay: 0.69 g.g\(^{-1}\) (0.68 – 0.69)
Regrowth hay: 0.80 g.g\(^{-1}\) (0.75 – 0.83)

CASE STUDY
Grass silage: 0.82 g.g\(^{-1}\)
Field-dried hay: 0.72 g.g\(^{-1}\)
Regrowth hay: 0.75 g.g\(^{-1}\)

Same order of magnitude than case-study and close to INRA feed values table for permanent pastures in mountain areas
Grass intake at pasture (kg DM·d⁻¹)

12.9 (11.6 - 13.3)

Digesibility of ingested grass

0.83 (0.78 - 0.86)
Validation sous-modèle troupeau

Enchaînement de 6 parcelles entre le 24 mai et le 13 juillet

Hyp:
- Variabilité des PL observées (P4, P5, P6)
- Difficulté de paramétrage du couvert végétal à partir des données de biomasse à 5 cm et hauteur d’herbe

RMSD: 1.4 kg PLprod.VLL⁻¹.j⁻¹
Soit 6,5% de la PL moyenne

Biais et rotation minime
Manque de corrélations

Structure model cohérente et prédiction correcte
Validation sous-modèle troupeau - hiver

RMSD: 2.1 kg Plprod.VLL\(^{-1}\).j\(^{-1}\)
Soit 6,8% de la PL moyenne

Hyp:
- 1\ère semaine lactation
- Variabilité interindividuelle
- Estimation de la Plpot (lot 2)

Biais et rotation minime
Dispersion des données
Structure modèle cohérente et prédiction correcte