Optimizing meadow management using temperature sums

In the Upper Rhine region, grasslands are an important feed resource for cattle farms. If properly managed, they can contribute to the food and protein self-sufficiency of livestock farms by providing high-quality forage. The use of benchmarks such as temperature sums should facilitate their exploitation by helping farmers to anticipate the benchmark stages of their grasslands.

Temperature sums: a grassland management tool

Good management of grassland, whether by grazing or harvesting, means **exploiting it at the right stage**, i.e. finding a compromise between yield, feed value and animal needs**.**

The availability of water, nutrients, sunlight and temperature are essential for plant growth. However, at the end of winter, the primary factor limiting grass growth remains **air temperature**, and this factor will condition the appearance of the different physiological stages of the grasses present in permanent grasslands.

The 5 main reference stages for permanent grasslands are based on the phenological stage of the grasses that make them up: vegetation start, 5cm ear of corn, early heading, full heading, flowering. These stages are associated with meadow management guidelines that optimize both forage quantity and quality: putting to grass, dethatching, early mowing, late mowing, etc. For a given grass, reaching these stages requires a certain level of temperature accumulation, also known as "temperature sum". With climate change, this criterion varies considerably from one year to the next, and calendar date references are becoming obsolete. On the other hand, the use of temperature sums has the advantage of taking into account both the climatic context of the year and the location of the meadow.

The 5 main stages are associated with benchmarks for managing grassland to optimise both forage quantity and quality.

Figure 1: The main phenological stages of forage grasses (from Fourrage Mieux 2014)

A variety of permanent grasslands

Work carried out by INRA Toulouse (Cruz et al., 2010) has made it possible to classify different permanent grasslands according to the functional types of the dominant grasses that make them up. This typology is based on a number of functional traits shared by species of the same type: leaf dry matter content, leaf area, leaf life, flowering date, maximum plant height, leaf resistance to breakage. It allows us to define each species according to its habitat preference and use value (ability to fulfill a given function in a forage system).

Grassland type	A	B	b	C	D
Soil fertility	Fertile environment	Fertile environment	Fertile environment	Low-fertility environment	Low-fertility environment
Plant size	Small	Large		Small	Medium
Precocity	Very early	Fairly early	Quite late	Fairly early	Very late
usage	Early and frequent grazing	Early mowing and/or late haying	Mowing and summer grazing	Not very suitable for mowing. Good feed value at vegetative stage.	Typical flora of little-used summer pastures or rangelands. Low forage value
Representative species	*English ryegrass, woolly coot, sweet vernal grass, timothy, meadow foxtail...*	*orchardgrass, meadow fescue, tall fescue, Kentucky bluegrass, upright bromegrass...*	*common bentgrass, timothy, creeping couch grass, meadow bluegrass, soft coot...*	*cretelle, red fescue, sheep's fescue...*	*brachypode penné, Loudun oats, nard raide, canche des champs, molinie bleue...*

Table 1: Typology of French permanent grasslands (after Cruz et al. 2010)

By definition, a natural grassland is multi-species, and will never support a single group of species. If a functional type represents more than 66% of all grasses, the prairie will be considered of the same type as the dominant functional type.
Ex: For a meadow where type A, B and C grasses represent respectively 25%, 70% and 5% of the grasses, we consider that the meadow is type B.
If the dominant functional type represents less than 66% of the grasses, the grassland will be classified according to its component types as soon as they represent more than 20% of all grasses.
Ex: For a meadow where type B, b and C grasses represent 45%, 40% and 5% of the grasses respectively, the meadow is considered to be type Bb.

Applying this typology to Swiss meadows

Swiss grasslands are grouped according to four intensities of use, from "intensive" to "extensive", resulting in **13** common **grassland types** on the northern slopes of the Alps and in the Jura. They are named after the most representative species, which are mainly indicator plants.

- Intensive use: very frequent mowing/grazing with a high level of fertilization
  - ✓ *Italian ryegrass meadow*
  - ✓ *Mow-and-graze meadow with English ryegrass and Kentucky bluegrass*
  - ✓ *Meadow foxtail meadow*
- Semi-intensive use: mowing/grazing
  - ✓ *Cocksfoot meadow*
  - ✓ *Crested dog's-tail grassland*
- Low-intensity use
  - ✓ *Orchard grass meadow*
  - ✓ *Yellow oat meadow*
  - ✓ *Dandelion pasture*
  - ✓ *Grassland with bentgrass and red fescue*
  - ✓ *Moist, rich grassland with 2 subtypes: marram grassland and rush grassland*
- Extensive use
  - ✓ *Brome grass prairie*
  - ✓ *Spikenard pasture*
  - ✓ *Litter meadow with 3 sub-types: mullein meadow, Davall's sedge meadow and brown sedge meadow*

Use	Intensive			Mi-intensive		Low intensity					Extensive	
Meadow type	Italian ryegrass meadow	English ryegrass and Kentucky bluegrass meadow	Meadow foxtail meadow	Cocksfoot meadow	Crested dog's-tail grassland	Orchard grass meadow	Yellow oat meadow	Dandelion pasture	Grassland with bentgrass and red fescue	Moist, rich meadow	Brome grass prairie	Spike-nard meadow
Main valuation	Mowing	Mowing +grazing	Mowing	Mowing	Pasture	Mowing + grazing	Mowing	Pasture	Mowing+grazing/ Grazing	Pasture	Mowing	Grazing
Precocity	Early	Very early	Early	Fairly early	Fairly early	Late	Late	Late	Late	Late	Very late	Late
Fertility	Strong	Strong	Strong	Interme-diary	Interme-diary		Low	Interme-diary	Low	Low	Low	Low
Productivity	Strong	Strong	Quite strong	Quite strong	Interme-diary	Interme-diary	Low	Very Low	Very Low	Very low	Very low	Very low
French typology correspon-dance	A	A	A	B	C	B	C	b	C	D	D	D

Table 2: Typology of Swiss grasslands and correspondence with French permanent grassland types (from the knowledge platform of the Association pour le développement de la Culture Fourragère eADCF)

Management guidelines adapted to the diversity of grasslands

The typology of permanent grasslands, based primarily on species earliness and soil fertility, has enabled us to define the sums of temperatures required to reach the different benchmark stages for each type of grassland, and thus to anticipate the corresponding management practices to be implemented, both for grazing management and for 1st mowing.

Meadow type		A or B	b	C
Precocity		Very early to early	Late	Fairly early
Soil fertility		High	Intermediate	Low
Productivity		Strong	Average	Low
Prairie Stadium	**Management practices**	**Temperature sums (in degrees day)**		
Vegetation start	Grazing turnout	250 to 300	400	400
5 cm ear	tillering	500	800	800
Ear 10 cm	End 1er of grazing	500 to 600	1000	900
Early heading	Early mowing: silage, wrapping	700t o 800	1200	*Not suitable for mowing*
Full heading	Early hay	800 to 1100	1500	
Flowering	Late hay	900 to 1200	1600	

Table 3: Correspondence between temperature sums, grass physiological stages and best management practices for permanent grasslands type A or B, b and C

How to calculate temperature sums

Cumulative mean daily temperatures are a good estimator of the different phenological stages of plants. However, a number of calculation rules need to be observed to adapt to the specific context of prairie grasses.

1. *The daily average* is based on the raw minimum and maximum values from the local weather station, without any prior correction.
2. *The vegetation zero* for meadows is the base 0°C.
3. *The daily averages are capped* at 18°C, as the growth acceleration phenomenon is considered to stop above this threshold.
4. *The initialization date for* cumulative daily temperatures is February 01.
5. Altitude leads to slower growth due to colder average daily temperatures. The *altitude difference* between the weather station and the plot is taken into account by applying a correction of -0.6°C to the daily average for every 100-meter rise in altitude.

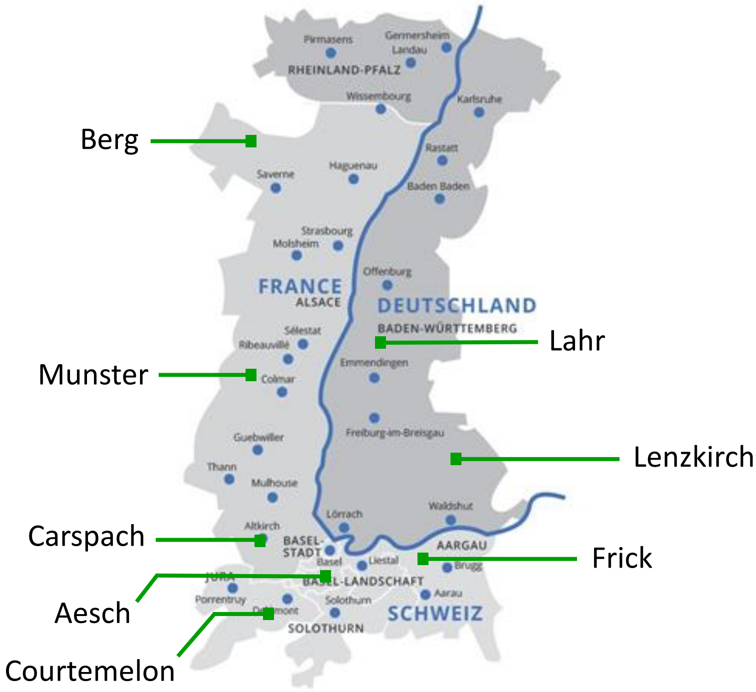
In practice:

- **For each day from 01/02 onwards, calculate the average daily temperature (Minimum temperature + Maximum temperature)/2**
- **If the average daily temperature is < 0°C, use an average daily temperature of 0°C.**
  Ex: If the average temperature is -5°C, note 0°C
- **If the average daily temperature is between 0°C and 18°C, use this value,**
  Ex: If the average temperature is 13°C, we note 13°C
- **If the average daily temperature is > 18°C, use an average daily temperature of 18°C.**
  Ex: If the average temperature is 21°C, we note 18°C.
- **Add the daily average to obtain the sum of temperatures in degrees days since 01/02**

Source : Parc Naturel Régional Lorraine

Benchmarks for different weather stations

The following tables show the average dates at which the various milestones have been reached at selected weather stations over the last ten years (2014-2023).



German weather stations

Weather station	LAHR (156 m)			LENZKIRCH-RUHBÜHL (854 m)		
Date reached	Median	Min.	Max.	Median	Min.	Max.
300 Degree-days (Grassing)	March 22	March 11	9-Apr.	19-Apr.	7-Apr.	27-Apr.
400 Degree-days	1-Apr.	March 21	15-Apr.	May 2nd	21-Apr.	May 10
500 Degree-days (End of trimming - thorn at 5 cm)	13-Apr.	5-Apr.	23-Apr.	May 11	May 1	May 21st
700 Degree-days (Early mowing-Early heading)	May 1	21-Apr.	May 9th	May 28	May 21st	June 8
800 Degree-days	May 8	28-Apr.	May 16	June 5	May 31st	June 14
1000 Degree-days (Early hay-Early flowering)	May 22	May 14	May 31st	June 18	June 14	June 27
1100 Degree-days	May 29	May 21st	June 6	June 24	June 20	July 3
1200 Degree-days (Medium hay-Flowering)	June 4	May 27	June 12	1-july	June 27	July 10

Table 4: Dates for reaching certain milestones in grassland, based on the sum of mean temperatures base 0-18 accumulated since February 01 over the period 2014-2023 (Source: LKV).

Swiss weather stations

Weather station	AESCH (382 m)			COURTEMELON (450 m)			FRICK (390 m)		
Date reached	Median	Min.	Maxi.	Median	Min.	Max.	Median	Min.	Max.
300 Degree-days (Grassing)	March 19	March 10	11-Apr.	March 27	March 16	14-Apr.	March 25	March 16	13-Apr.
400 Degree-days	March 30	March 19	18-Apr.	9-Apr.	1-Apr.	21-Apr.	5-Apr.	March 7	19-Apr.
500 Degree-days (end of trimming at 5 cm)	11-Apr.	Apr. 4	23-Apr.	21-Apr.	11-Apr.	28-Apr.	18-Apr.	8-Apr.	26-Apr.
700 Degree-days (Early mowing-Early heading)	29-Apr.	18-Apr.	May 10	May 9th	28-Apr.	May 16	May 6	25-Apr.	May 13
800 Degree-days	May 9th	24-Apr.	May 19th	May 17	May 6	May 25	May 15	May 3	May 22
1000 Degree-days (Early hay-Early flowering)	May 24	May 8	June 1	May 30	May 22	June 8	May 28	May 18	June 5
1100 Degree-days	May 30	May 16	June 7	June 5	May 29	June 14	June 2	May 25	June 11
1200 Degree-days (Medium hay-Flowering)	June 5	May 22	June 13	June 11	June 5	June 19	June 8	June 1	June 17

Table 5: Dates for reaching a number of grassland milestones based on the sum of mean temperatures base 0-18 accumulated since February 01 over the period 2014-2023 (Source: Agrométéo- Agroscope)

French weather stations

Weather station	BERG (300 m)			CARSPACH (332 m)			MUNSTER (420 m)		
Date reached	Median	Min.	Maxi.	Median	Min.	Max.	Median	Min.	Max.
300 Degree-days (Grassing)	March 25	March 18	13-Apr.	March 22	March 13	10-Apr.	March 25	March 16	13-Apr.
400 Degree-days	6-Apr.	March 31	20-Apr.	1-Apr.	March 25	18-Apr.	6-Apr.	March 30	20-Apr.
500 Degree-days (End of trimming - thorn at 5 cm)	18-Apr.	7-Apr.	28-Apr.	15-Apr.	7-Apr.	24-Apr.	19-Apr.	8-Apr.	27-Apr.
700 Degree-days (Early mowing-Early heading)	May 6	25-Apr.	May 13	May 2nd	22-Apr.	May 9th	May 6	26-Apr.	May 13
800 Degree-days	May 13	May 4	May 22	May 11	29-Apr.	May 18	May 15	May 4	May 22
1000 Degree-days (Early hay-Early flowering)	May 28	May 20	June 4	May 25	May 15	June 2	May 29	May 20	June 6
1100 Degree-days	June 3	May 27	June 10	May 31st	May 22	June 8	June 4	May 27	June 11
1200 Degree-days (Medium hay-Flowering)	June 9	June 2	June 16	June 5	May 28	June 13	June 10	June 3	June 17

Table 6: Dates for reaching certain milestones in grassland based on the sum of mean temperatures base 0-18 accumulated since February 01 over the period 2014-2023 (Source: Météo France)

Relationship between temperature sum, yield and forage quality in 1st cycle

As part of the Obs-Herbe network, the Swiss national grassland observatory set up by Agroscope, 23 intensive permanent grasslands were monitored from 2017 to 2019. On the basis of 4 samples taken at regular intervals between the start of sprouting and first mowing each year, it was possible to measure yields as well as nitrogen, fiber and ash contents, enabling energy and nitrogen values to be calculated and linked to the temperature sums recorded during sampling.
By demonstrating the correlation between temperature sums and yields, as well as between temperature sums and feed values, this work has provided the table below determining yields and feed values as a function of temperature sums.

Degree-days	Yield *(Tonne DM/ha)*	Protein *(g/kg)*	Digestibility *(%)*	Energy : NEL *(MJ/kg)*	BREAD *(g/kg)*
550	2.89	165.2	78.6	6.5	110.0
600	3.24	155.9	77.4	6.4	103.7
650	3.58	146.6	76.2	6.3	97.4
700	3.93	137.4	75	6.2	91.2
750	4.27	128.1	73.8	6	84.9
800	4.61	118.8	72.6	5.9	78.7
900	5.30	100.2	70.2	5.7	66.1

NEL: net energy milk - DM: dry matter - g/kg: grams per kilogram - MJ/kg: megajoules per kilogram
PAIN: absorbable proteins in the intestine synthesized from degradable nitrogenous matter

Table 7: Relationship between temperature sum, yield and forage quality based on 23 Swiss meadows monitored over 3 years (Source: Agroscope)

Source :
Swiss Agricultural Research

Management of subsequent grazing cycles

To improve grassland management, it's important to consider grass growth patterns throughout the entire season, not only in spring.

This means that, after initial exploitation (severe grazing, mowing), plants are left with only a reduced leaf surface and must therefore mobilize their reserves to produce new leaves. During this period, growth slows considerably. As this leaf surface regenerates, the plants will capture more and more light to produce biomass through photosynthesis. As a result, the yield of the grassland becomes higher and higher, and faster and faster, until the grass reaches the 3-leaf stage. Beyond the 3-leaf stage, grassland growth slows down to zero. In fact, a grass blade generally bears only 3 (or 4) leaves: the appearance of an additional leaf leads to the senescence and death of the oldest leaf.

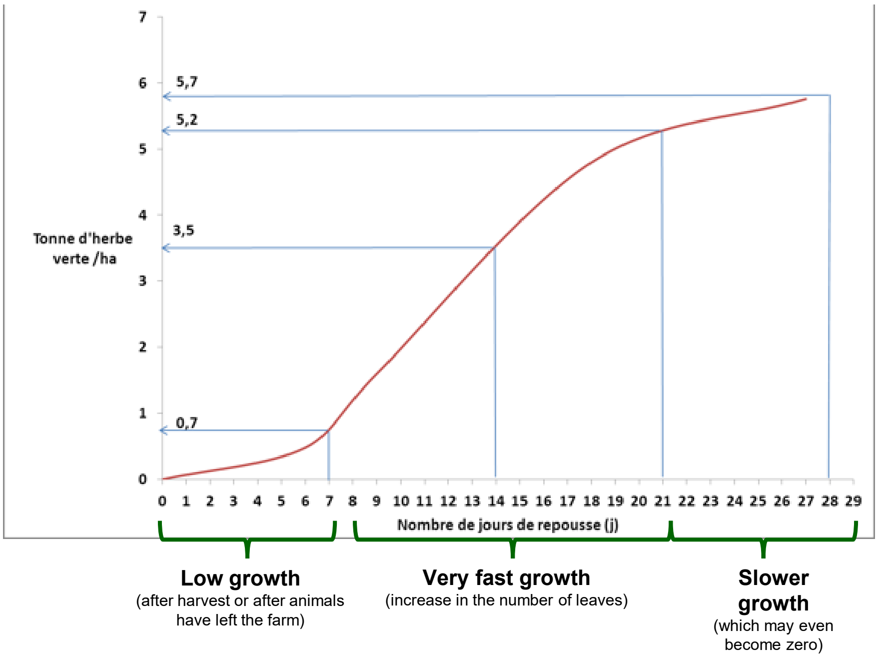


Figure 2:
Grass growth curve (after André Voisin 1957)

The return to previously used grassland (grazing, mowing) should therefore take place neither too early nor too late. Harvesting too early limits the replenishment of plant reserves, leading to dwarfing and eventual disappearance. Conversely, harvesting too late leads to wastage, as the oldest leaves disappear.

Meadow resting time should therefore be based on the 3-leaf stage, and will depend on the season, soil and climate conditions, and the type of meadow. It will be around 20 days in spring, and 35 to 40 days, or even longer depending on water deficit and temperature, in summer and autumn.

Leaf life, a grazing management indicator for the following cycles

In the summer, temperature sums alone are no longer sufficient to control grazing, as very often the factor limiting regrowth is the level of rainfall. However, there is a direct link between grass leaf life and temperature sums. The warmer the weather, the faster the vegetative cycles.

Leaf life is a feature that reflects the recycling of leaf tissue. Leaf life span (LLS) varies from species to species and conditions mowing and grazing practices. Thus, late use of species with short LOS will result in a high loss of biomass through senescence, whereas early use of species with long LOS will penalize their lifespan through a lack of adaptation to too-frequent defoliation.

Types of grass	Leaf life (in degree-days)
Type A	800
Type B	1000
Type b	830
Type C	1100
Type D	1100

Table 9: Leaf life (in degree-days) of different types of grass (after Cruz et al, 2010)

In practice, if an RGA leaf dies after 800 degree-days, mowing (or grazing) should be carried out within 40 to 45 days of first harvesting. For orchardgrass or tall fescue, whose leaf life is around 1,000 degree-days, this harvesting cycle should take place within 50 to 60 days after first harvesting.

Conclusion

Grassland management requires a great deal of technical skill, and in particular a good knowledge of the phenological stages of the species that make up the grassland, in order to provide sufficient quantities of quality grass (palatability, digestibility, feed value). Temperature sums are a real decision-making tool to help advisors and farmers identify these stages and implement good grassland management practices. They are available, for example, through the weekly publications of the French Grass Growth Monitoring Networks.

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