Identification of relevant environmental descriptors

Based on previous experiences and a literature review the most relevant environmental descriptors were selected and tested by means of field experiments. These included: (i) the temperature-humidity index (THI), (ii) the cattle stocking system (rotational stocking, continuous stocking or strip-grazing), (iii) the botanical composition of the grasslands, (iv) the net grassland productivity in terms of Net Energy (NE) and/or energy-corrected milk (ECM) per unit grassland area, and (v) the behaviour of dairy cows within grazing herds as recorded with SensOor® technology.

In two of our experiments in the Netherlands, we have tested the accuracy of the Sensoor® technology. The main result was that there was a good agreement between the observed activity 'grazing' and its record. However, in case of ruminating cows the quality of the recorded data was less good.

Temperature-humidity index and cattle breed

The treshold value of the THI for heat stress in dairy cattle is about 10% higher for Jerseys compared to both Holstein-Friesians (HF) and dual-purpose breeds: ±79 vs. ±72. This is one of the reasons why Jersey cows are gaining popularity nowadays in a world facing rising global temperatures. In two of our experiments we have used Jerseys. HF cows have only one advantage and that is the higher annual milk production per cow, also in terms of energy. Regarding all other important traits, Jerseys are superior: (i) longer grazing time due to their larger digestive tract per unit liveweight, (ii) shorter mastication and rumination time, (iii) lower maintenance costs per cow due to their lower individual liveweight, (iv) higher yield of milk solids at herd level per unit grassland area, (v) better persistence under harsh conditions and fewer cases of lameness and hoof problems, and (vi) their meat can be qualified as excellent because of the tender, well-marbled structure containing a high content of good fatty acids for human consumption and its richness in f.i. calcium. However, the meat prices for dual-purpose cows are still superior.

Cattle stocking systems, botanical composition and net grassland productivity

In the 1970s, comparative trials were started in Great Britain, Germany, Belgium and The Netherlands to sort out whether continuous stocking with cattle on one large pasture throughout the whole grazing season (e.g. 50 dairy cows on 15 ha) could compete with rotational stocking in terms of cattle output (milk and/or meat). The latter system was by far the most popular dairy cattle stocking system during those days in Northwestern-Europe and characterized by rotational grazing cycles of about four days in relatively small paddocks.

In all of these comparative studies, no clear differences in the annual output per unit grassland area were observed in terms of milk production and/or liveweight gain between the two cattle stocking systems (Ernst et al., 1980; Lantinga & Schlepers, 1985). Nevertheless, from a

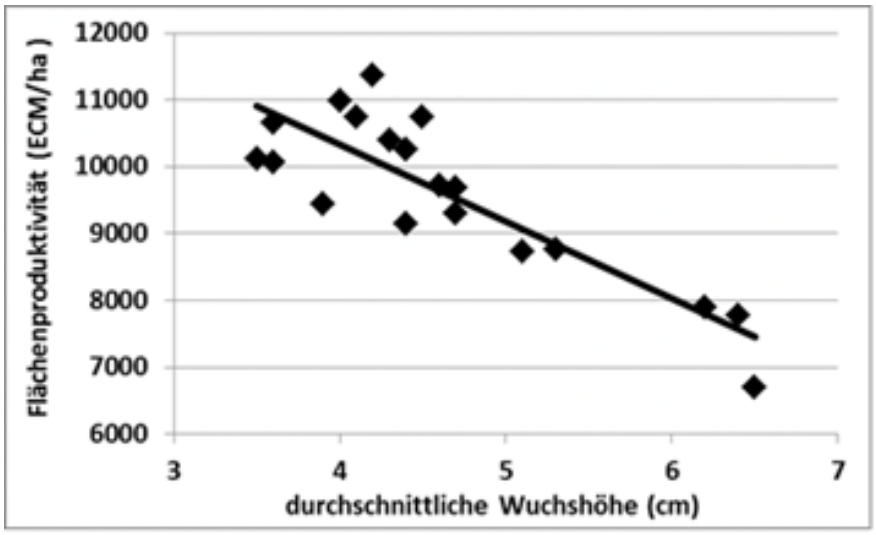
grassland management viewpoint it was concluded that continuous stocking has a number of practical advantages compared to rotational stocking (Ernst et al., 1980; Lantinga, 1985):

- Much smaller fluctuations in herbage allowance in terms of kg dry matter (DM) per cow per day above a minimum grazing height of about 4 cm -> a more or less constant daily herbage intake level by the cows throughout the whole grazing season;
- Less labour needs (more than 50%) for fertilization, fodder conservation and pasture topping;
- Less sward damage problems during wet periods as a result of herbage trampling due to (i) a much lower stocking density in the grazed area, and (ii) a considerably denser grass sward;
- No invasions in established swards with unwished tall dicot weeds (e.g. chickweed and docks) and weed grasses (e.g. couch grass, soft brome and Yorkshire fog) due to a rather constant low grazing height of about 4 cm throughout the grazing season leading to a dense vegetation dominated by perennial ryegrass, white clover, dandelion, plantain, creeping buttercups and yarrow in NW-Europe;
- Longer grazing time, but shorter rumination time for all cattle breeds.

Lantinga (2000) demonstrated that under proper grassland management, grass-clover swards receiving only cattle slurry can be just as productive as monocultures of perennial ryegrass monocultures supplied with artificial fertilizers next to cattle slurry. In this multi-year experiment seed mixtures consisting of diploid and tetraploid perennial ryegrass, white clover and red clover were used. The dairy herd of about 90 HF cows was grazing on a continuously stocked grass-clover pasture of 14 ha during daytime only. Besides, grazing sheep were used as biological weed suppressors (Olsen & Lacey, 1994) as well as for cleaning the grazing residues left by the dairy cattle in the vicinity of dung pats (Lantinga et al., 2013). As a result of this sward management strategy, four years after its establishment hardly any unwanted plant species were present.

During recent years, Leisen (Ökoteam Landwirtschaftskammer NRW Münster, Germany) has demonstrated that continuous stocking on commercial dairy farms is performing best in terms of kg milk per cow per day from grazed herbage, as well as per ha of grassland, when the grazed sward height is maintained around 4 cm throughout the grazing season (see Figure below). Note that this height only refers to the frequently grazed areas of the sward and does not include the rejected areas around e.g. dung pats. This conclusion is in agreement with our earlier observations (see above) and collected data on an organic dairy farm with Jersey cows (https://www.remeker.nl/?lang=en) within the framework of our current project (period 2016-2018; see below the report on the obtained results).

For the calculation of the net grassland productivity, three published methods were evaluated: (i) Schleepers & Lantinga (1985), (ii) Aarts et al. (2015) and (iii) Leisen (2018). It appeared that there exist only minor differences between these three methods. For this reason, it was decided to make use of the procedure developed by Leisen (2018) since it has the advantage that it makes use of a user-friendly Excel file. Besides, the net grassland productivity is here calculated in two different ways: (i) Net Energy for Lactation (NEL) per ha and (ii) Energy-Corrected Milk (ECM) per ha.



ECM (Energy-Corrected Milk; 4% fat; 3.3% protein) = M (kg milk) * (0.337 + 0.116 * % fat + 0.06 * % protein) (Leisen, 2018)

Conclusion

- No clear differences have been detected between Holstein-Friesian (HF) and dual-purpose cows with respect to their response to the Temperature-Humidity Index (THI).
- However, the threshold value of the THI for heat stress in dairy cattle is about 10% higher for Jerseys compared to both Holstein-Friesians (HF) and dual-purpose breeds: ±79 vs. ±72.
- Moreover, Jersey cows have a number of other advantages: (i) lower maintenance costs due to their relatively low liveweight, (ii) longer grazing time, (iii) shorter mastication and rumination time, (iv) more efficient milk production, (v) highest milk production of all cow breeds per unit grassland area, and (vi) less cases of lameness and hoof problems.
- For all cattle breeds, continuous stocking is preferred over rotational or strip stocking.

I. Case study at an organic dairy farm on sandy soil with a herd of about 90 adult Jersey cows. Since the year 2016 the cattle stocking system was changed from rotational to continuous stocking.

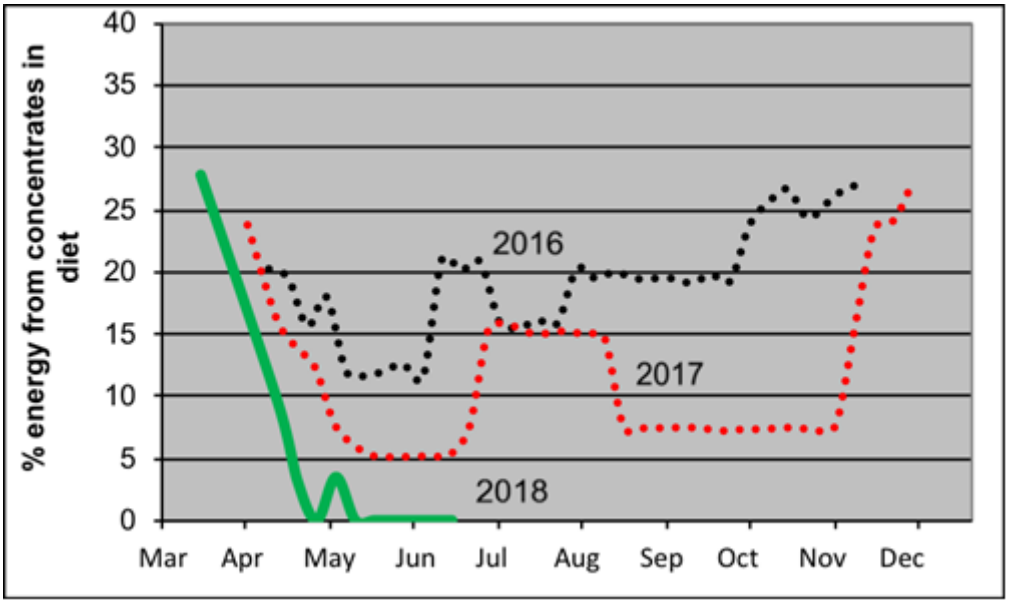


Fig. 1. Contribution of supplied concentrates to the diet of the cows (2016-2018)

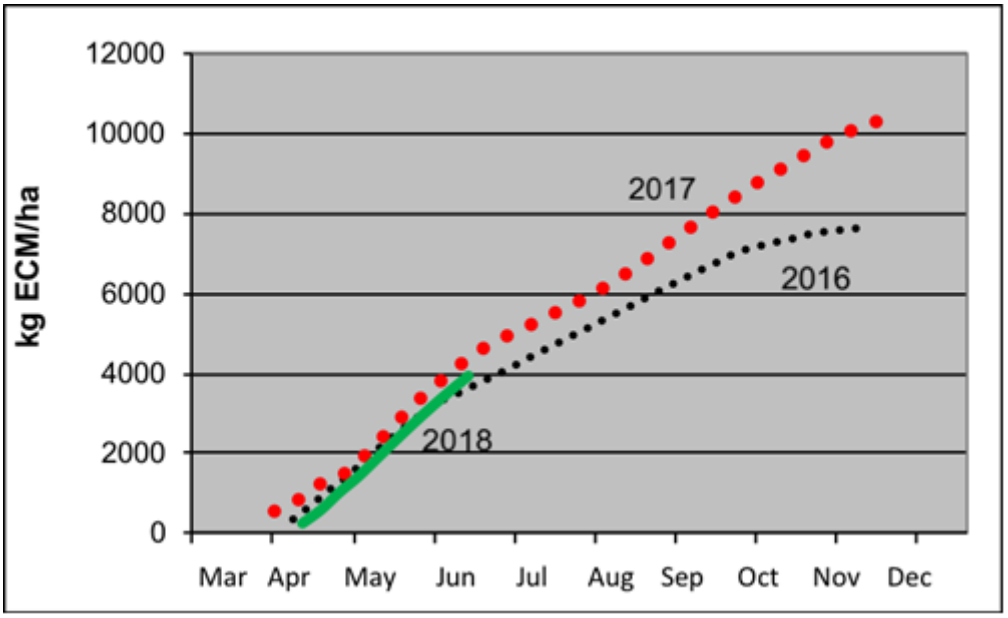


Fig. 2. Cumulative milk production (ECM) per ha from grazed herbage (2016-2018)

2016: (i) Excess of rainfall between early June and early July -> bad grazing conditions; (ii) Shortage of rainfall in early spring and between mid- September and early November -> reduced herbage production.

2017: (i) Excess of rainfall between the end of June and mid-September. However, there were hardly any problems with too wet pastures due to more anecic earthworms which make vertical burrows leading to improved water infiltration (disappeared some 20 years ago after

ploughing and reseeding). (iii) Excellent autumn weather for herbage growth leading to very good grazing conditions.

2018: (i) After two years of continuous stocking in all pasture fields the swards were very dense. As a result, hardly any broadleaf and narrowleaf (grass) weed species were left. Since early May the dairy cows were not supplemented with concentrates or other feed sources any longer. This resulted in significant cost savings whereas the daily milk production per cow was not reduced.

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