Maintain forage yields in long- and short-term grasslands in Norway

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Abstract
Various reasons have been invoked explaining the low renovation activity in Norwegian grassland farming: swards are often located in marginal areas, ploughing and reseeding gives low or no yield in the renovation year, and it may be unprofitable to establish a new sward. The establishment of new leys can also prove difficult in seasons with unfavourable weather conditions. Thus, farmers prefer long-term or permanent swards as opposed to ploughed and reseeded swards. The hypotheses of this study is that under equal management conditions, permanent and temporary swards (leys) that are reseeded frequently are equally productive. We present results from an experimental field trial at Særheim (58°47'N 5°41'E), SW Norway, which was established 1968. The experiment includes grass plots maintained without ploughing for more than 50 years, and frequently (every 3 to 6 years) ploughed treatments. Three different fertiliser strategies are included: mineral fertiliser (210 N kg ha^{-1}) and cattle slurry in combination with mineral fertiliser (210 kg and 340 N kg ha^{-1}). In 2016, the frequently ploughed treatments and half of the 25-years-old sward was renewed by ploughing and reseeding with grass-clover seed mixtures. The second half of the 25-years-old sward was sod-seeded using perennial ryegrass (*Lollium perenne*) only in 2017 and grass-clover mixtures in 2019. Herbage yields and forage quality was determined after each of the three annual cuts. In the first year after reseeding, 2017, the leys had significantly higher forage yield than the 50- and 25-year-old permanent grasslands regardless fertilisation strategy. This difference between leys and long-term grasslands was evened out in the second production year. In 2019, the permanent grassland yielded significantly more than in the leys except in the plots, which received 210 kg N ha^{-1} in combined form. There was no difference in herbage yield between swards that had been renovated by sod-seeding or by ploughing and reseeding.

Introduction
Improving grassland productivity and thereby improving livestock production is a main part of grassland management. Fertilisation, use of valuable forage species and improved grazing and harvesting practices are common measures to improve grassland productivity (Frame. 1992). Grassland renewal is mainly a reaction to a decline in yield and nutritive value (Kayser et al., 2018) e.g. after stressful environmental conditions reducing the proportion of desirable species in the sward. However, in general grasslands systems are rather stable. In Western and Northern Norway, a significant number of swards are more than 10 years old. Various reasons have been invoked to explain the low renovation activity in Norwegian grassland farming: swards are often located in marginal areas, ploughing and reseeding gives low or no yield in the renovation year, and it may be unprofitable to establish a new sward. The establishment of new leys can also prove difficult in seasons with unfavourable weather conditions and is threatened by low winter survival in the year of reseeding. Thus, farmers prefer long-term or permanent swards as opposed to reseeded swards. In recent years, interest in long-term grasslands has increased in Europe too due to the general need for reducing the costs of forage production and a need to maintain or increase soil carbon. Several studies have concluded that under equal management conditions, permanent and temporary swards are equally productive (Hopkins *et al*., 1990; Nevens and Reheul, 2003). However, in northern Norway, Nesheim (1986) found that dry matter yields (DMY) declined after the fifth year and 11-20 years old leys had the lowest DMY, whereas swards older than 20 years had intermediate yields. In SW Norway, Lundekvam and Myhr (1975) showed strong correlation between age of the grassland, weed density and DMY. In their study, long-term grasslands produced high DMY in 15 years. Here, we present result from an experimental field trial at Særheim (58°47'N 5°41'E) in SW Norway. This trial, which has been maintained since 1968, includes plots which have been maintained without ploughing for more than 50 years, as well as frequently ploughed and reseeded treatments. The hypotheses is that under equal management conditions, permanent and regularly (every 3 to 6 years) reseeded swards are equally productive.

Methods and Study Site
The long-term trial was established at NIBIO research stations in SW Norway, Særheim, Rogaland (58.8°N 5.6°E 80 m asl.) in 1968. The soil was developed on morainic material. It has a humus rich well-defined plough

layer overlying a moderately well-drained silty sand subsoil. Until 2016, the trials included four main-plot treatments with different sward ages established with three replicates per trial:
PG: Permanent grassland established in 1968
S-PG: Semi-permanent grassland established in 1992
LEY-6: 6-year ley
LEY-3: 3-year ley.
Various management regimes were included on sub-plots, including cutting-grazing regimes (with/without spring and autumn grazing) and mineral fertilizer only until 1992. Treatments with cattle slurry were included from 1992. Both ley treatments were ploughed prior to each 3- or 6-year reseeding.
In 2016 the experimental design was modified by splitting the main treatments, and S-PG was renewed either by ploughing (S-PGp) or direct sod-seeding (S-PGs). LEY-6 and LEY-3 were also ploughed and reseeded and production period extended to 12 (LEY-12) and 6 years (LEY-6), respectively. In 2016, a grass-clover mixture was used in all plots renewed by ploughing. In 25-year old S-PGs plots English ryegrass (*Lollium perenne*) was sown in 2017 and sod-seeded grass-clover mixture in 2019. Three different fertilisation practices included on sub-sub-plots. Nitrogen (N) applied in form of mineral fertiliser only (MF; 210 kg N/ha) and cattle slurry combined with mineral fertiliser (CS+MF; 210 and 340 kg N/ha). The plant biomass was harvested according common practice in the region, three times during the growing season. In 2017, however, only two cuts were performed because of excessive precipitation in the second part of growing season. The herbage yields and forage quality were determined after each cut. The data were analysed by general linear model and one-ways ANOVA.

Results

In the first production year, 2017, the frequently ploughed and reseeded leys had significantly higher forage yield than permanent (>50 years without ploughing) and semi-permanent (25 years) grassland, regardless fertilisation strategy (Fig.1). This difference between ley and long-term grasslands disappeared in the following year and in 2019, DM yields of PG treatments were significantly greater than for reseeded treatments S-PGs and LEY-6 ($P<0.007$) (not shown). Average DM yields for four production years and all treatments are showed in Fig.2. Under equal fertilisation practices, both long-and short-term grasslands produced equally large DM yield. There was no difference in DM yield between swards that had been renovated by sod-seeding or by ploughing and reseeding (Fig. 2).

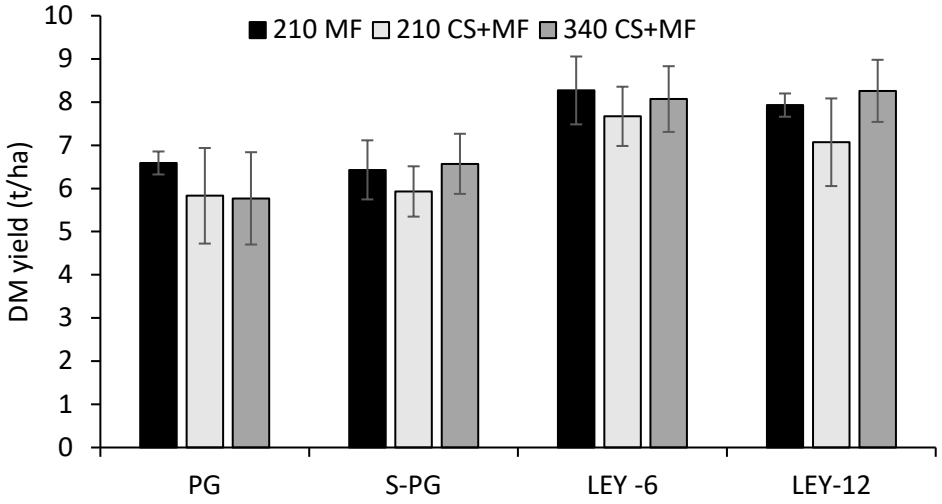

Figure 1 Average DM yield in 2017 for permanent grassland (PG), semi-permanent grassland (S-PG) and reseeded ley in 2016 (LEY-6 and LEY12) fertilised with mineral fertiliser only (210 MF) or cattle slurry in combination with mineral fertiliser (210 CS+MF and 340 CS+MF).

Fertilisation strategy significantly affected forage production. Particularly, treatment 210 CF+MF resulted in significantly lower forage DM yield (P<0.5) compared to treatment 210 MF and 340 CS+MF. On average for all production years the 210 MF treatment resulted in equal DM yields as the 340 CS+MF one (Fig.3).

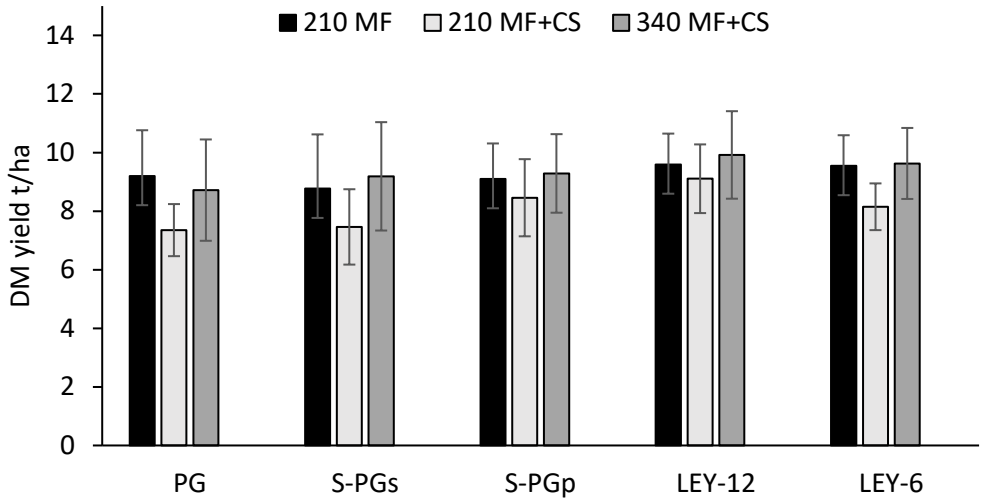

Figure 2. Average DM yield for four forage production years and for permanent grassland (PG), semi-permanent grassland renewed by sod-seeding (S-PGs) and ploughing (S-PGp) and reseeded ley in 2016 (LEY-6 and LEY12) fertilised with mineral fertiliser only (210 MF) or cattle slurry in combination with mineral fertiliser (210 CS+MF and 340 CS+MF).

There were no differences in forage quality between treatments (data is not showed).

Discussion [Conclusions/Implications]

Our hypothesis, that under equal management conditions permanent and regularly reseeded (every 3 to 6 years) swards are equally productive, was supported. The 50 years old permanent grassland produced good quantity and quality of forage yield and even more in 2019 than particularly treatments of four years old leys. Assessment of botanical composition in PG showed that forage biomass contained more than 60% of cultivated grass species like perennial ryegrass, meadow fescue (*Festuca pratensis*), smooth grass (*Poa pratensis*) and timothy (*Phleum pratensis*) (data not showed). These are all species that can provide high yields under Norwegian conditions. The results throughout suggest that cultivated PG can maintain good and stable forage production under appropriate fertilisation practice over several decades (Fg.2). Our study also shows that sod-seeding can be a good alternative to ploughing, which may be beneficial for the climate as grasslands may store significant amounts of C (Soussana et al., 2004). However, sod-seeding might unsuccess and then it might result in resource and yield loss. More research is needed to determine under which conditions sod-seeding will be successful and under which conditions ploughing before reseeding is needed (Rueda-Ayala and Höglind 2019).

In order to obtain acceptable forage yields, the nutrient availability for plant growth is important. The lowest level of N applied in spring as cattle slurry resulted in lower yields than when the same level of N was applied as mineral fertilizer, indicating that N from organic sources is little available just after application or partly lost by ammonia emission. However, fertilisation strategies that include cattle slurry might be a good management practise and might give more advantages than disadvantages in long-term.

In conclusion, our findings show that permanent grasslands are productive and can give good yields with good quality over several decades.

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