Faculty of Applied Ecology, Agricultural Sciences and Biotechnology

Sukebate Aletengqimuke

Master thesis

A comparative study on plant intake in lactating and dry stage beef cattle grazing on boreal forest pastures with different stocking densities in Norway

En sammenlignende undersøkelse av planteopptak hos melkeproduserende og tørre kjøttfe som går på skogsbeite med ulik husdyrtetthet i Norge

Master in Sustainable Agriculture

2018

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Abstract

Livestock grazing in forests or on other unimproved outlying lands has for long been an important farming practice in Norway and has been a way farmers could use rural resources to increase production and sustain diversity and landscapes. In recent years, the role of beef cattle on outlying lands has increased due to a growing demand for beef in Norway. Little is known about how to optimize such production, for example on how the reproductive state of the cattle (lactating and dry state) influence the plant intakes when grazing on boreal pastures with different stocking densities. Such information is valuable when making management decisions. A study was started in which this master thesis was a part. The aim of the current work was to compare plant intakes in lactating and dry beef cattle grazing on forest pastures with high and low stocking densities. Cattle faeces were collected during the summer and autumn 2016 and the material included samples from 22 lactating beef cattle and 23 dry beef cattle. The samples were examined by microhistological analysis methods, which could differentiate plant species and plant genera based on visual plant fragments in the faeces. Significant differences between lactating and dry cattle were detected for the amount of grasses and deciduous species fragments in the faeces ($P<0.05$ for both). Faeces from lactating cows showed more grass fragments (74.8% ± 8.8) with a corresponding lower percentage of deciduous species (4.5% ± 2.6) compared to dry cows (71.8% ± 11.5 and 4.8% ± 2.8, respectively). An interaction between study area and reproductive state was detected. Lactating cows in the high-density area had more grasses in their faces compared to dry cows, while both lactating and dry cows had similar intakes from grass species in the low stocking density area. The results are discussed and should be relevant for practitioners using boreal pastures for grazing beef cattle.

Keywords: Reproductive state, stocking density, biodiversity, plant intake, pasture.

Norwegian summary

Husdyr på beite i skog eller annen utmark har lenge vært en viktig praksis i jordbruket i Norge. På denne måten kunne bønder ta i bruk lokale ressurser for å øke produksjonen og pleie landskapet og artsmangfoldet i landskapet. De siste årene har utmarksbeite til ammeku blitt mer aktuelt, særlig på grunn av økt etterspørsel etter denne typen kjøtt i Norge. Kunnskapen om denne produksjonsformen er derimot noe begrenset, for eksempel om hvordan det at de går med eller uten kalv (produserer melk eller ikke) påvirker opptaket av planter på skogsbeite med ulik husdyrtetthet. Slik kunnskap er verdifull i forhold til å ta avgjørelser i selve driften. Et arbeid ble derfor satt i gang hvor denne master-oppgaven inngår i et større prosjekt. Målet med masteroppgaven var å sammenligne opptak av planter i ammeku med og uten kalv som går på skogsbeite med henholdsvis høy eller lav husdyrtetthet. Prøver fra kuruker ble samlet inn i løpet av sommeren og høsten 2016 og i materialet inngikk 22 slike prøver fra kuer med kalv og 23 uten kalv. Prøvene ble undersøkt ved hjelp av en analysemetode som kunne differensiere mellom ulike plantearter eller planteslekter basert på synlige strukturer i planterestene i kumøkka. Statistisk sikre forskjeller mellom ku med og uten kalv kunne påvises for rester av grasarter såvel som for rester av arter av løvtre i møkka ($P < 0.05$ for begge). Møkka fra ku med kalv viste en høyere andel grasfragmenter (74.8% ± 8.8) og en tilsvarende lavere andel av løvtrearter (4.5% ± 2.6)sammenligna med møkka fra ku uten kalv (hvor de tilsvarende verdiene var henholdsvis 71.8% ± 11.5 og 4.8% ± 2.8). En sammenheng mellom beiteområde og om kuene gikk med eller uten kalv kunne påvises. Kyr med kalv i området med høy husdyrtetthet hadde mer grasarter i møkka sammenlignet med kyr uten kalv, mens kyr både med og uten kalv hadde samme inntak av grasarter i området med lav husdyrtetthet. Resultatene er diskutert og burde være relevante for praktikere som utnytter skogsbeite til ammeku.

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1. Introduction

As human population increase, urbanization continues and technology develops, agriculture has experienced big changes over the last decades. Over the globe, production systems have been developed to support the increasing demands of food and this has been done through the use of improved plant varieties and livestock strains, the use of artificial fertilizers and pesticides, and the applications of improved agricultural technologies (Gilland, 2002). Although modern agriculture has succeeded, at least partly, to meet the global demands, the production has been intensified and still need to increase. The productivity (production per unit of land) has increased very much, and many places, especially in the periphery, this has led to a reduction in the demands for croplands (Rudel et al., 2009). Structural changes in agricultural management and land use has led to a biodiversity loss (Smith et al., 2007), partly through an intensification of the high-productive agriculture and forestry lands (Tscharntke, Klein, Kruess, Steffan‐Dewenter, & Thies, 2005) but also because of an abandoning of the low-productive outlands, often termed unimproved areas (MacDonald et al., 2000).

Borlaug (2007) suggested that a future agricultural development on a global scale should not only focus on improving productivity but also be concerned on balancing the relations between population growth, food production, and environmental sustainability. To maintain biodiversity and sustainability of ecosystems in unimproved lands, developing a knowledge-based sustainable practice for the areas is crucial. Livestock grazing is commonly known as a useful management practise to exploit efficiently rural resources and increase local production but also to mitigate biodiversity loss in unimproved pastures (Celaya, Ferreira, García, García, & Osoro, 2011). In Norway, livestock grazing on unimproved lands has an important role in the traditional agricultural management system.

1.1 Livestock grazing practice in Norway

Norway has a unique livestock management system, feeding livestock indoor in winter and grazing in outlying forests or mountain pastures during summer. In Norway, agricultural, arable land accounts for only 3.4% (120,746km^2) of the total area while mountains and forests occupy 45.4% and 37.3% of the total land area, respectively (Strand, 2013). Due to this scarcity of the arable land, and by using outlying lands as summer pastures, infield pastures can be prioritized for winter feeds or for production of food plants. Using the outlying lands has been an important tradition and a set of utilizing low-productive, unimproved lands for agricultural production (Austrheim, Solberg, Mysterud, Daverdin, & Andersen, 2008; Potthoff, 2004; Skonhoft, Austrheim, & Mysterud, 2010). The production is characterized by releasing the animals for freely grazing on the not cultivated areas in spring and for over the summer before they are taken home in autumn (Sæther, Sickel, Norderhaug, Sickel, & Vangen, 2006). "Not cultivated" means that no synthetic inputs or cultivations carried out- the lands are not tilled, nor seeded, fertilized or treated with any pesticides or any other remedies other than eventually used in forest plantings. Hereafter, such lands are referred to as unimproved grazing areas, or simply unimproved land or outlying lands. The unimproved grazing system in Norway can be regarded as a sustainable livestock management practice. Reksen, Tverdal, and Ropstad (1999) highlighted that sustainable agriculture does not require subsidies of exogenous energy from finite resources, such as fossil fuels, or environmentally sensitive resources, such as fertilizers and pesticides. From that perspective, grazing livestock on unimproved lands certainly is an efficient way of producing food in a sustainable way.

The history of livestock grazing in Norway can be traced back to the last Ice Age, some 10,000 years ago (Hjelle, Hufthammer, & Bergsvik, 2006; Sickel, Ihse, Norderhaug, & Sickel, 2004). With the development of summer farming practice, the utilization of unimproved lands were intensified during 16th century (Olsson, Austrheim, & Grenne, 2000). In the early 19th century, summer grazing including forest and mountain pastures was the most important livestock management system in Norway and covered huge mountain areas and large parts of the forests (Sickel et al., 2004). At the same time, the number of seasonal summer farms (termed "seter or sæter" in Norwegian) peaked. These were summer homes where people lived and looked after the livestock, milked and made cheese and butter, or from where the sheep were released and gathered. The summer farms were located both in the mountains and in the forests, often with a small area of cultivated land around the houses. From the mid-19th century, there was a dramatic reduction in the number of these summer farms in Norway, declining from 53000 in 1850 to only 2000 in 2004 (Sickel et al., 2004). The reduction was mainly due to structural changes in the agriculture with intensifications in fertile and accessible areas and agricultural abandonments in poor and inaccessible areas of the country (Bryn & Hemsing, 2012; MacDonald et al., 2000). One could see a transition from a traditional extensive livestock farming to a more intensive management practice without utilizing the outlying lands. Over time, there has also been a shift in the breeding of livestock but still most of the Norwegian cattle are raised from a mixed dairy-meat race, although with the specific and good traits for milk production.

Although there has been a general reduction in the utilization of the unimproved lands, opportunities can be reflected in different management systems and local adaptations to the natural resources (Lind, Ruderaas, & Rødven, 2013). Using livestock grazing management of the forests may become an important tool for balancing biodiversity and forest re-growth (Bryn, Dourojeanni, Hemsing, & O'Donnell, 2013).

1.2 Pasturing in clear-cut boreal forest areas in Norway

In Norway, as forest areas and woodland cover almost 40% of the land area and approximately 80% of the total forest are owned by farmers, there is a huge access for farmers to graze their livestock on forest-based pastures (Hansen, Boe, & Okkenhaug, 2009). Livestock grazing play an important role in a forest pasture ecosystem and the grazing practice influences plant communities and diversity (Austrheim et al., 2008). Livestock grazing in a forest has an economic value. In commercial forests, a new generation of young tree need a time to establish and need at least 20 to 50 years from planting to cutting (Eid, Hoen, & Økseter, 2002). The slow payback rate brings hardship and long-time gaps for the owners of those forests after establishing of a new forest generation. Therefore, the benefit from combining forestry with grazing livestock on the area may increase the total income from an area. Clear-cuts in boreal forests are highly preferred by livestock in forest pastures and such areas provide an amount of different plant species for livestock (Tofastrud, et al., unpublished 2018). A study by Pykälä (2004) indicated that a high number of species with long-term persistent seeds will start germinating and growing after forest clear-cut practices. Due to such plant species abundance in the clear-cuts, it is valuable for cattle to graze on such areas. Rreleasing livestock to graze on clear-cuts is also beneficial for converting local resources into animal growth and economic value.

In addition, livestock grazing on outfield areas will have impact on the area by what they select to eat. Herbal plants and grasses represent an important part of the boreal ecosystem and the presence of such plants in the plant community is a main indicator for biodiversity changes in a forest pasture. In general and over the last 50 years or so, pastures have changed from herbage and grass communities to more shrub and tree dominated communities (Austrheim et al., 2008). These changes are results of reduced numbers of grazers in the forests, like less sheep, goats, cattle and horses, while the number of browser, like moose, red deer and roe deer, has increased correspondingly (Austrheim et al., 2008). Livestock grazers mainly graze on grass and herbage species whereas the browsers largely depend on woody plants such as trees and shrubs. The changes in the plant communities and current land use patterns may accelerate loss of plant diversity (Austrheim et al., 2008) as open grounds in a forests often have a high biodiversity value (Humphrey & Patterson, 2000).

During the last century, forest areas increased significantly in Norway, form 69km^2 in 1907 to 124 km^2 in 2007 (Bryn et al., 2013). Forest areas will probably continue to grow and forests will probably extend into new areas in the future (Bryn & Hemsing, 2012). Three main reasons for the forest growth pointed out by Bryn et al. (2013) were1) agricultural intensification in productive areas and abandonment of outfield lands, 2) afforestation, and 3) climate change. From the perspectives of sustainable agriculture and ecosystem conservation, the forest growth may have negative effects, and these are especially related to less plant diversity in the forest pastures (Bryn et al., 2013). Therefore, developing appropriate management strategies that could balance plant biodiversity and forestry would be of good value (Farruggia, Dumont, D'hour, Egal, & Petit, 2006). One such management practice could be the use of cattle for grazing in the forests.

1.3 Livestock on forest pastures

Cattle as grazing livestock have complex interactions with their pastures and environments, by grazing, behaviours, trampling, defecation as well as urination (Anna Hessle, Rutter, & Wallin, 2008). In a clear-cut forest pasture, cattle grazing has been shown to stimulate grass species but have some negative impacts on herbaceous and deciduous plants, this as grazing reduce the regrowth of those species (Belsky & Blumenthal, 1997; Hjeljord, Histøl, & Wam, 2014; Östlund, Zackrisson, & Axelsson, 1997). As cattle are not interested in eating shoots of Norway spruce (*Piceaabies*) (Huntsinger, 1996; Liss, 1988), which is the most important forestry plant in the country, grazing may be considered as positive for the commercial forestry. Cattle grazing may result in increased tree size and quality, due to positive effects on light for young trees but also competing better for nutrients and water (Hjeljord et al., 2014; Reid, McAvoy, & Salmon, 2012). Furthermore, the faeces and urine from cattle may serve as a natural fertilizer for the forest trees, recycling nutrient in the system.

However, high stocking densities of cattle on forest pastures have shown negative influences on the forest regeneration through trampling effects on young trees and influencing deciduous trees. A study conducted by Hjeljord et al. (2014) showed that cattle grazing was positively correlated to the proportion of damaged spruce trees, while sheep grazing had not the same relationship. The study also indicated that cattle grazing restricted the regrowth of deciduous trees by browsing the leaves of such trees (Hjeljord et al., 2014). When grazing on an unimproved pasture, cattle are generally less selective than sheep (Fraser, Theobald, Griffiths, Morris, & Moorby, 2009) and cattle have a huge amount of energy intakes. Due to a more selective grazing nature, sheep usually graze wider throughout a pasture than cattle do. However, sheep are very vulnerable to predation of an increasing number of big carnivores like brown bears (*Ursus arctos*) and wolves (*Canis lupus*) in South-Eastern Norway (Zimmermann, Wabakken, & Dötterer, 2003). Therefore, the government encouraged farmers to replaces sheep with beef cattle, as beef cattle are less vulnerable than sheep for such predation. Over the last decades, there has been a continuous change in the composition of released domestic animals, shifting from sheep and dairy cows to heavier breeds of beef cattle on forest pastures (Hjeljord et al., 2014).

1.4 Beef cattle on forest pastures

Beef cattle, after sheep, are the second most important and common grazers on unimproved pastures in Norway. In Hedmark County, the reduction in the number of livestock on unimproved land was significant in the second half of 20th century (Austrheim, Solberg, & Mysterud, 2011). There has also been a change in the compositions of grazers on unimproved pastures over the last 50 years. Dairy cows were the dominated grazers in unimproved pastures and they had the highest energy intakes. However, due to changes in the dairy production, the management shifted from the traditional livestock practices of a seasonal movement to the modern permanent infield managements, resulting in a decrease in the total number of dairy cows but an increase in average milk production per cow (Knutsen, 2006). As a consequence, there are only non-lactating dairy cattle in unimproved pastures and the number of beef cattle in unimproved pasture have increased correspondingly (Histøl, Hjeljord, & Wam, 2012).

In Norway, releasing cattle to graze on unimproved lands is regarded as good animal welfare and the government has established a mandatory rule for farmers, releasing their female cattle older than six months on summer pastures for at least eight weeks per year (Hansen et al., 2009). The regional authorities for Hedmark County pointed out a new action plan, " Regional development program for Hedmark, 2013-2016", and here they encouraged farmers to release more beef cattle on unimproved lands in order to exploit efficiently the rural recourses and increase agricultural productivities (Regionalt bygdeutviklings program for Hedmark 2013-2016,,, 2013; Yngve Rekdal, 2017). In this plan, foods production was aimed to increase by at least 20% by 2030, and beef production was also aimed to increase by 20% by 2020 (Yngve Rekdal, 2017). According to the plan, this could be obtained through a better utilization of the resources in unimproved areas. However, less knowledge about grazing cattle's diet and the possible intake differences between different cattle groups need a better understanding for making optimal decisions when utilize these resources.

1.5 Plant intake of cattle in different reproductive states

As already stated, cattle are commonly recognized as grazers and prefer to eat a great proportion of grass and herbaceous plants (Celaya et al., 2011), and they also eat leaves of deciduous trees and shrubs when available, but avoid to graze the needles of conifer trees as spruce and pine (Wehn, Pedersen, & Hanssen, 2011). Anna Hessle et al. (2008) detected that cattle are quite selective in the early grazing season (spring-summer) and that they grazed higher proportions of less preferred species (such as sedges, rushes and woody plants) later in the grazing season (Anna Hessle et al., 2008). Cattle also avoid grazing on wet areas dominated by sedges and rushes when dry areas were available (Anna Hessle et al., 2008).

In general, cattle prefer grass species such as *Avenella flexuosa*, *Deschampsia cespeitosa*, *Anthoxanthum odoratum.* and *Festuca onina spp* with high energy values (Bjor & Graffer, 1963). Those species are common species in unimproved pastures in Norway. Lunnan and Todnem (2011) reported that the energy value was highest in *Avenella flexuosa*, followed by *Deschampsia cespitosa* and *Carex spp*. A study from Farruggia et al. (2006) showed that beef cattle in different reproductive states (lactating and dry) grazed differently at the end of the grazing season on an extensively grazed natural mountain pasture in France. They also pointed out that lactating cattle with higher energy requirements were more selective than dry cattle and lactating cattle prefer grazing on the green patches with much grasses (Farruggia et al., 2006).

1.6 Purpose of this study

Several studies on cattle grazing have been conducted in Norway. The effects of cattle has been compared with other grazer (goats and sheep) or with browser (reindeer) and impacts have been measured on vegetation changes, for example as in the study of Wehn et al. (2011). A research carried out by Steine (2012) examined grazing selections of different livestock species, and animal welfare and economic values of those grazing animals on unimproved lands were included. Plant and vegetation preferences of different breeds of cattle have been compared in a study fromSæther et al. (2006). The effects of cattle grazing on deciduous trees and forest regeneration has been examined (Hjeljord et al., 2014) as the effects of cattle grazing on small rodents and nesting bird populations (Bøe, Hansen, Bjelkåsen, & Kroglund). The previous comparative study on plant intakes of grazing livestock have been made on different species and breeds in Norway, which could be largely explained by “differences in body size and the consequent allometric relationships with intake capacity, digestibility and selectivity” (Farruggia et al., 2006). However, few studies have compared influences of reproductive state (lactating and dry cattle) on plant intakes.

The main objective of this study was to identify the intakes of different plant species, plant genera and plant groups by comparing plant fragments in faecal samples of lactating and dry cattle grazing in areas with high and with low stocking densities, respectively. The hypothesis was that:

1) Due to differences in energy requirements for lactations, lactating cattle graze more on high-energy grass species (such as *Avenella flexuosa*) than dry cattle.

2) The plant intakes of beef cattle are affected by study sites.

2. MATERIALS AND METHODS

2.1 Study areas

This study was conducted in two forest pasture areas in Hedmark County in the southeast of Norway (Figure 1):

1. Stange/Romedal area (SRA) with low stocking density

2. Furnes/Vang area (FVA) with high stocking density.

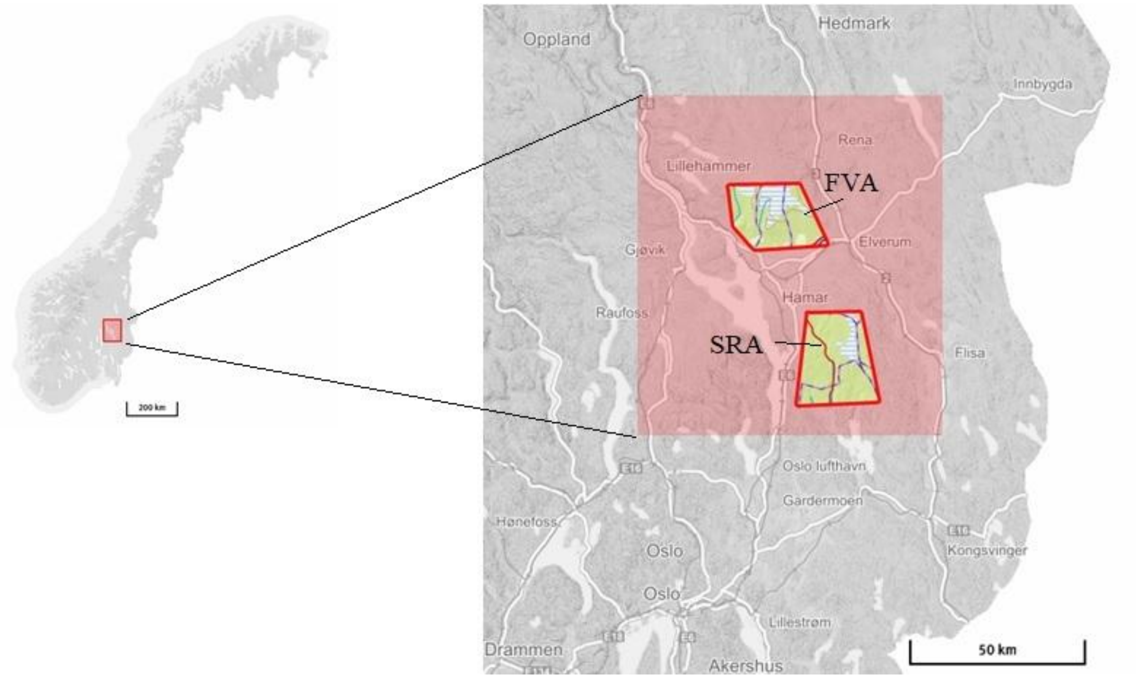

Figure 1. Locations of the two study areas Stange/ Romedal (SRA) and Furnes/ Vang (FVA) (Modified after: www.norgeskart.no)

2.1.1 Locations and climates of study areas

Both study areas are located in communal areas used for mixed purposes that include commercial forestry, recreational cabins, wild game hunting, and hiking. The communal areas are dominated by a typical boreal coniferous forest with a large proportion of spruce and a minor proportion of the deciduous forest, and also mainly focused on the production of Norway spruce (*Picea abies*) (Hjeljord et al., 2014). The vegetation types consist mainly of the blueberry-spruce-forest type (Yngve Rekdal, 2017). The clear-cuts areas normally range from two to three hectares (ha) within the larger forest areas, and these clear-cuts are replanted by saplings that need some years for the trees to get big (Hjeljord et al., 2014). During this time, these clear-cuts are the main places for forest pasturing.

The climate data is based on the local climate information of the nearest weather stations, which are Staur and Nord-Odal for SRA (Yngve Rekdal, 2017) and Løten for FVA (Y Rekdal, 2010). Both study areas are located in the northern boreal vegetation zone of the typical inland boreal forest area characterized by cold winters and warm summers. SRA (60°36' N, 11°24'E) is located in Stange municipality, with altitudes ranging from around 300 to 600 m above sea level, with annual precipitation around 735 mm and annual mean temperature around 3.6°C (Yngve Rekdal, 2017). FVA (60°57'N,11°1'E) belongs to Ringsaker and Hamar municipalities. This area has a higher overall altitude compared to SRA, here with altitudes in the range of 600-700m above sea level. The annual precipitation in FVA is a little lower (600-700mm) as the annual mean temperature (3.4°C) compared to SRA (Y Rekdal, 2010).

2.1.2 Grazing densities of the study areas

Based on vegetation maps, each vegetation types was grouped into three foraging classes due the amount and quality of the common pasture plants, which again give indicating values for how many cattle one hectare of land normally could hold. The forage classes were; Less Good (LG, 0.05– 0.08 beef cows ha^{-1}), Good (G, 0.08- 0.12 beef cows ha^{-1}) and Very Good (VG, 0.12-0.17 beef cows ha^{-1}). The distribution of the three foraging classes was summarized and to be 21% and 29% LG, 76% and 67% G, and 2% and 4% VG in SRA and FVA, respectively.

In SRA, the total study area was 150 km^2, but 75-78% of this was accessible for the cattle. In FVA, the total study area was 100 km^2 but almost 40% of FVA is swamping forest, which is wet area. Livestock, especially cows, are very reluctant to utilize these wet areas when other resources are available (Anna Hessle et al., 2008).

Based on actual numbers of grazing livestock in the two areas the livestock densities were calculated to be 0.04 cows per ha in SRA and 0.16 cows per ha in FVA (Y Rekdal, 2010;

Yngve Rekdal, 2017). This represented 38% and 148% of the area's grazing capacity in SRA and FVA, respectively. Hence, we considered SRA to be stocked at a "Low density" and FVA at a "High density".

2.1.3 Plant cover of the study areas

Blueberry vegetation types are dominant in SRA with 75% of the total area, which again can be divided into 58% blueberry-spruce-forest and 17% blueberry-pine-forest (Yngve Rekdal, 2017). Lichen- and heather-pine-forest makes up 13% of the area while grass and herbaceous areas make up only 2% (Yngve Rekdal, 2017).

In FVA, the dominant vegetation type is also blueberry types, covering 33% of the area, while lichen-and heather-pine-forest occupies 23% (Y Rekdal, 2010). The richer meadow-spruce forest is only 2.4% (Y Rekdal, 2010). The swamping forest accounts for 40% of the total area and *Carex spp* is the dominated species in swamp areas of FVA.

2.2 Faeces sampling and plant composition identification

2.2.1 Sampling

Faeces samples were collected in 2016, during two different seasons:

- Summer season (from 10th of June to 12th of July)
- Autumn season (from the 1st of August to 9th of September).

Only samples from beef cows in different reproductive states were included. In total, 75 samples were collected from both study areas, for which 36 faecal samples were collected from 11 lactating beef cows and 12 dry beef cows in FVA while 38 faecal samples were gathered from 11 lactating cows and 11 dry cows in SRA.

The faeces were picked up, about 2 dl for each sample, just after the cattle had deposited them during the daily grazing periods. When the faeces samples were still warm, they were collected and cooled in plastic bags with labels of the date and cattle's ID and kept in the freezer (about -18℃) before they are analysed.

2.2.2 Micro-histological analysis

Plant compositions in faecal samples are of main importance for calculating grazing capacity for cattle and they highly influence the cattle diets. It is, therefore, important to understand the patterns and characteristics of plant intakes of cattle grazing on unimproved lands in different stocking densities. One of the common methods analysing botanical compositions of ruminant diets is faecal analysis by *Microhistological Analysis* through determining the botanical compositions of herbivores diets by plant cell wall in faeces (Alipayo, Valdez, Holechek, & Cardenas, 1992; Holechek, 1982).

These faecal samples were prepared for *Microhistological Analysis* according to the procedures of Garcia-Gonzalez (1984). The analyses were carried out at NMBU, Ås by Barbro Kristina Dahlberg. All fragments intersecting a 1 mm wide line along 40 mm long transects were examined. The transects were placed 3 mm apart. A minimum of 200 fragments was identified on each slide (A Hessle, Wissman, Bertilsson, & Burstedt, 2008; Sæther et al., 2006).

In total, 74 faecal samples were analysed for total number of fragments. Thirty plant species and plant genera were identified form the fragments and divided into six groups (Table 1). Four plant species/genera (*Equisetum spp.*, *Filicatae*, *Bryophytae* and *Liliaceae*) were not included in any of the six groups since each of them was from other different plant group and had a little contribute to the total amount of plant fragments.

Table 1. The group deviation of 26 plant species and plant genera from faecal analysis.

Plant Group	Plant Species/Genera
Total grass	*Deschampsia cespitosa*, *Avenlla flexuosa, Molinia caerulea, Anthoxanthum odoratum, Phleum spp., Calamagrostis spp., Poa spp.,Festuca rubra, Festuca pratensis, Aqrostis spp., Nardus stricta.Alopecurus spp.* and *Poaceae*
Total sedges	*Carex spp.* and *Cyperaceae*
Total deciduous	*Betula pubescens, Betula verrucosa, Salix spp. and Sorbus aucuparia*
Total heathers	*Vaccinium myrtillus* and *Calluna vulgaris*
Total coniferous	*Picea abies, Pinus sylvestris* and *Juniiperus communies*
Herbs	herbs (herbaceous plants)

The varying digestibility of the plants and its impact on the feasibility of micro-histological analysis has been raised as a weak point of the method (Sæther et al., 2006). These effects were considered as low in this study since the main propose was to compare plant intakes of same breed in different reproductive states. It is doubtless that the digestibility of a same plant would not differ for cattle in a same breed with different reproductive states.

2.3 Data analysis and statistic models

In this study, all plant species, plant genera and plant groups with less than 4 % observed fragments (calculated based on mean values over all samples) were not included in the further statistical analysis, as they made up a little portion of the total amount of fragments and thus have minor effects on the total picture. Although some species, such as *Salix spp., Anthoxanthum odoratum, Phleum spp.* and *Festuca pratensis* have high nutrient values (Sæther et al., 2006), they contributed very little for the total amount of fragments and were excluded from statistical analysis. Duo to the high digestibility of herbs and uncertainties of identification of herb species, herbs were not included in this statistical analysis, even though they have high nutrient values and a total mean value as a group higher than 4%.

All statistical analysis was processed in the software program R (Version 3.4.4). A linear model was applied where the proportions of each plant species/genera/group were investigated as dependent variables with fixed covariance, including reproductive state (lactating and dry), study area (SRA and FVA), season (summer and autumn) and their interactions. Fifteen models were built for the proportion of each plant species/genera/group and tested for cumulative Akaike information criterion (AIC). Paired F-tests were utilized to compare nested models with the lowest AIC. The model with the lowest AIC and the simplest structure was selected as the best model. The confidence interval (CI; 95%) was used for all the performed tests. The best models based on these analyses are given in Table 2.

Table 2. The best model for each plant species, plant genera and plant group.

Dependent variables	Independent variables
Total grass=	μ + Season + Study area + Reproductive states + Study area * Reproductive states + e
Total sedges=	μ + Season + Study area + Reproductive states + e
Total deciduous=	Intercept + Season + Study area + Reproductive states + Study area *Reproductive states + e
Avenella flexuosa=	μ + Season + Study area + Reproductive states + Study area *Reproductive states + Study area * Season+ e
Deschampsia cespitosa=	μ + Season + Study area + e
Carex spp.=	μ + Season + Study area + e
Poaceae=	μ + Season + e
Festuca rubra=	μ + Season + Study area + Reproductive states + Study area * Season +Season* Reproductive states + e

3. RESULTS

3.1 Overall plant fragment compositions in faeces samples

On average and across all samples, there were 460 plant fragments observed in each faecal sample with a standard deviation (S.D.) of ±21. In total, 30 different plant species and genera were identified from the faecal samples. An overview of the proportional mean values of each of them is given in Table 3.

The highest mean value was detected for the grass group (73.3% ± 10.2). The grasses consisted of 12 identified species and genera, and an unrecognized species, most likely within the *Poaceae*. The sedge group was the group with the second highest proportion of observed fragments in the faecal samples (11.4% ± 7.2), followed by the deciduous group (4.7% ± 2.7).

On average and across all samples, *Avenella flexuosa* and *Deschampsia cespitosa* were the two single species that had the highest proportions of observed fragments (26.5% ± 14.1 and 25.9 ± 10.8, respectively) in the faecal samples. Both are grass species commonly found in Norwegian forest pastures. The single species with the third highest value was *Carex spp*, contributing to 11.1% (± 7.2).

Table 3. Mean values (by percentages %) of the proportions of single plant species, plant genera and plant groups fragment across all faeces samples. Bold fonts indicate a higher value than 4% and standard deviation (S.D.) is given in parenthesis.

Plant species, plant genera or plant group	Mean (SD)	Plant species, plant genera or plant group	Mean (SD)
Downy birch, *Betula pubescens*	0.25 (0.39)	Meadow fescue, *Festuca pratensis*	2.66 (1.44)
Silver birch, *Betula verrucosa*	0.03 (0.17)	Bent-grass, *Aqrostis spp*	1.58 (0.88)
Birch, *Betula spp.*	0.85 (0.95)	Matgrass, *Nardus stricta*	0.05 (0.20)
Hedge apple, *Salix spp.*	3.53 (2.50)	Foxtail grass, *Alopecurus spp*	0.02 (0.06)
Mountain-ash, *Sorbus aucuparia*	0.02 (0.07)	**Unidentified grass, *Poaceae***	**8.63 (3.80)**
Blueberry, *Vaccinium myrtillus*	2.86 (3.02)	**Sedge species, *Carex spp.***	**11.11(7.24)**
Heather, *Calluna vulgaris*	0.53 (0.80)	Sedge species, *Cyperaceae*	0.26 (0.69)
Scots pine, *Pinus sylvestris*	1.29 (1.41)	Horsetail, *Equisetum spp.*	0.09 (0.26)
Norway spruce, *Picea abies*	0.01 (0.06)	*Filieatae*	0.44 (1.02)
Juniper, *Juniperus communies*	0.00 (0.02)	Moss, *Bryophyta*	0.79 (0.77)
Tufted hair-grass, *Deschampsia cespitosa*	**25.91 (10.82)**	Lily family, *Liliaceae*	0.00 (0.02)
Wavy hair-grass, *Avenella flexuosa*	**26.54 (14.10)**	Herbs	4.57 (2.18)
Moor grass, *Molinia caerulea*	0.80 (1.96)	**Total grass**	**73.27 (10.20)**
Sweet vernal grass, *Anthoxanthum odoratum*	0.05 (0.14)	**Total deciduous**	**4.68 (2.69)**
Timothy, *Phleum spp.*	0.17 (0.29)	Total coniferous	1.30 (1.41)
Red-grasses, *Calamagrostis spp*	0.06 (0.13)	Total heathers	3.40 (3.67)
Meadow grass, *Poa spp.*	1.14 (1.12)	**Total sedges**	**11.37 (7.19)**
Red fescue, *Festuca rubra*	**5.67 (2.79)**	Total fragments	460 (21.19)

3.2 Results from the statistic models

3.2.1 Models with plant groups

Table 4 presents the results from the linear models for plant groups of total grass, total sedges and total deciduous, showing the effects of study areas, seasons, reproductive states, and interactions between study area and reproductive states on the components for each of these plant groups in faecal samples. Study area has significant effects on plant groups of total grass ($P< 0.001$) and total sedges ($P< 0.001$). The proportions of observed fragments for total grass species (Figure 2) in faecal samples were higher in the low stocking density area (76.9% ± 6.6) compared to the high stocking density area (69.0% ± 12.0). Furthermore, higher proportions of fragments for sedges species (Figure 2) were detected in the high stocking density area (14.5% ±7.61) compared with those in the low stocking density area (8.1% ± 5.0).

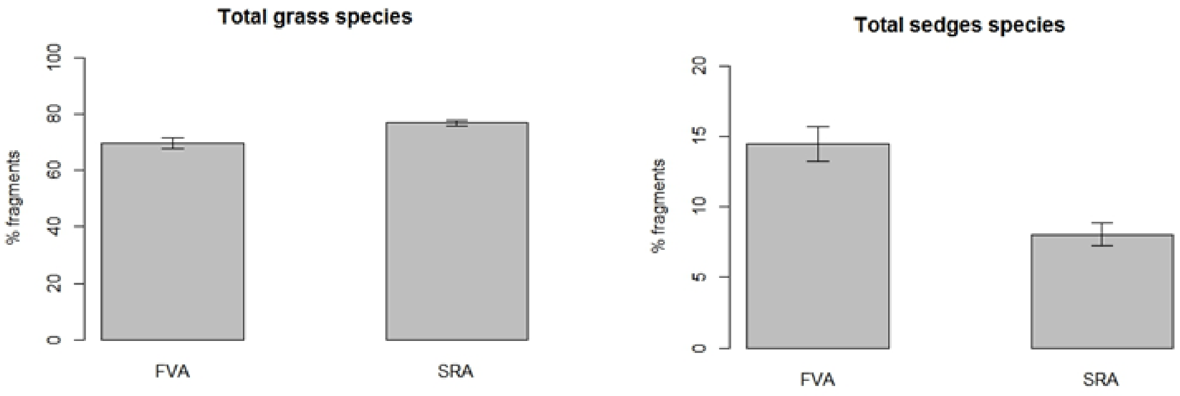

Figure 2. Mean values of the observed proportions of total grass species fragments (left) and total sedges species fragment (right) in faecal samples of beef cattle in study areas of high (FVA) and low (SRA) stocking densities.

The effects of season were also significant ($P < 0.01$) both for total grass and for total sedges groups, indicating that these plant groups are grazed differently in two seasons. More fragments of total grass species in the faecal samples were observed in summer (76.7% ± 10.7) than those in autumn (69.8% ± 8.7) whereas fewer fragments of total sedges species in the faecal samples were identified in summer (8.8% ± 6.3) in contrast to those in autumn (13.9 % ± 7.2).

Table 4. Coefficient estimates, 95% confidence intervals (CI) and standard errors (SE) of the best-ranked linear models describing the variation in fragments of plant groups in the faecal samples (*: interactions between two variables).

Model		Estimate	CI (2.5%-97.5%)	SE
Total grass	Intercept	63.74	(59.47, 68.00)	2.14
	Season (summer)	6.20	(2.05, 10.35)	2.08
	Study area (SRA)	11.43	(5.61, 17.24)	2.92
	Reproductive states (lactating)	7.09	(1.27, 12.91)	2.92
	Study area (SRA) * Reproductive states(lactating)	-10.02	(-18.33, -1.71)	4.17
Total sedges	Intercept	16.90	(14.23, 19.56)	1.34
	Season (summer)	-4.71	(-7.54, -1.89)	1.42
	Study area (SRA)	-6.17	(-9.00, -3.34)	1.42
	Reproductive states (lactating)	-0.35	（-3.18, 2.49）	1.42
Total deciduous	Intercept	4.49	(3.30, 5.68)	0.60
	Season (summer)	0.69	(-0.47, 1.85)	0.58
	Study area (SRA)	0.00	(-1.63, 1.63)	0.82
	Reproductive states (lactating)	-1.99	(-3.62, -0.36)	0.82
	Study area (SRA) * Reproductive states(lactating)	3.16	(0.83, 5.48)	1.17

The effect of reproductive states was significant ($P< 0.05$) both for total grass and for total deciduous groups. Dry cows had higher intakes of total deciduous species (4.8% ± 2.8) and lower intakes of total grass species (71.8% ± 11.5) compared with lactating cows (4.5% ± 2.62 and 74.8% ± 8.8, for the two plant groups respectively). The interaction between study area and reproductive states was also significant for the total grass group ($P< 0.05$) as well as for the total deciduous group ($P<0.01$). This demonstrates that lactating cattle and dry cattle grazed differently on these two plant groups at two study areas (Figure 3 and 4).

When analyzing both lactating and dry cows separately, the effect of study area was not significant on the intakes of total grass species for lactating cows, but significant for the intakes of total grass species for dry cows. Dry cows grazed higher proportion of total grass species (87.4% ± 4.7) in the area with low grazing density than those in the high grazing density area (66.4% ± 12.6) (Figure 3). However, there is an opposite trend for the intakes of total deciduous species (Figure 4), showing that study area has no significant effects on the intakes of total deciduous species for dry cows, but has significant effects on those for lactating cows. The intakes of total deciduous species for lactating cattle were higher in the low stocking density area (6.0% ±2.6) compared with those in the high stocking density area (2.9% ±1.3).

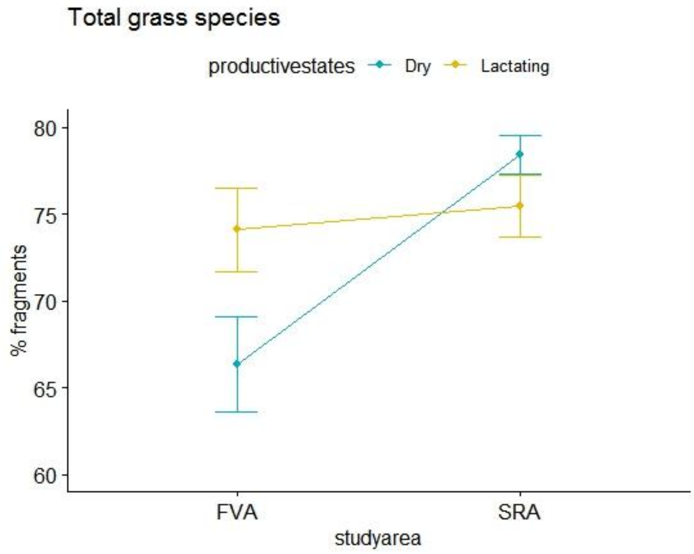

Figure 3. Mean values of the observed proportions of fragments of total grass species in faecal samples by lactating and dry cattle in study areas of high (FVA) and low (SRA) stocking densities.

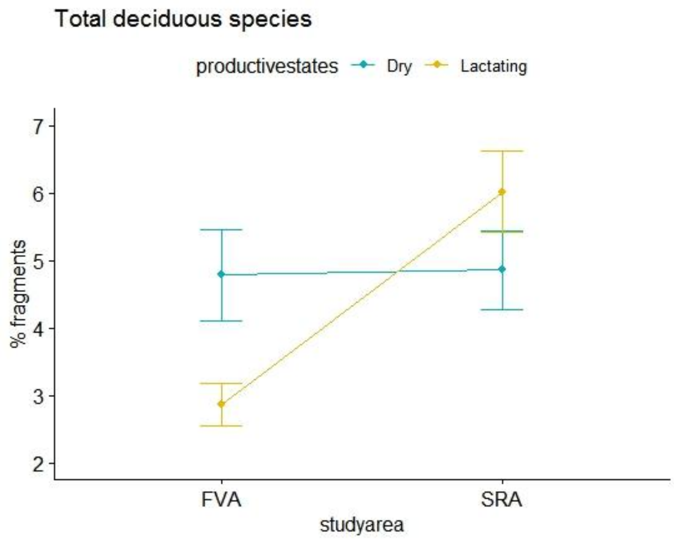

Figure 4. Mean values of the observed proportions of fragments of total deciduous species in faecal samples by lactating and dry cattle in study areas of high (FVA) and low (SRA) stocking densities.

3.2.2 Models with plant species and plant genera

Table 5 presents the results from the linear models investigating the plant species and plant genera with higher than 4 % mean values in the faecal samples by indicator covariance of study area, season, reproductive states and their interactions. Study area has significant effects on single species of *Deschampsia cespitosa* and *Avenella flexuosa*, and plant genera of *Carex spp* (P< 0.001 for all) (Figure 5). More fragments of *Avenella flexuosa* were observed in faecal samples from cows in the low stocking density area (35.5% ± 13.3) than the samples taken in the high stocking density area (18.0% ± 8.5). Conversely, fragments of *Deschampsia cespitosa* and *Carex spp* were identified more in faecal samples from cows in the high stocking density area (32.1% ± 9.9and 14.4% ± 7.6, respectively) compared with the samples taken in the low grazing density area (19.3% ± 7.4 and 7.6% ± 4.9, respectively).

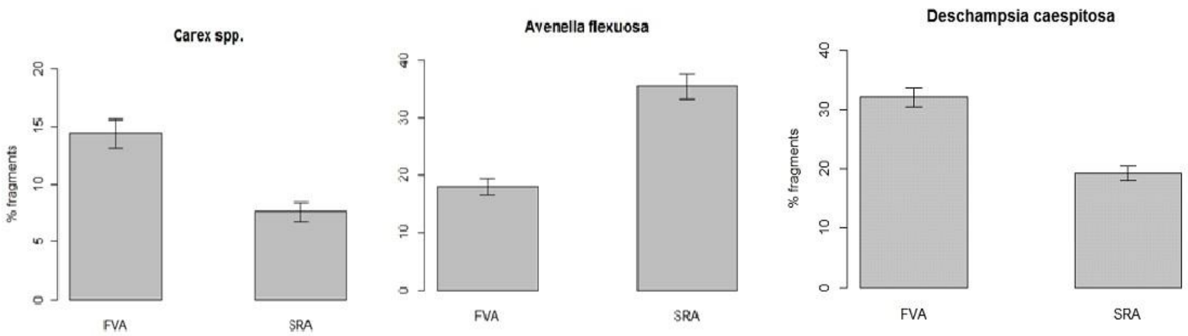

Figure 5. Mean values of the observed proportions of fragments for *Carex spp*, for *Avenella flexuosa* and for *Deschampsia cespitosa* (from left to right) in faecal samples of beef cattle in study areas of high (FVA) and low (SRA) stocking densities.

The effect of season was significant (P<0.01) for the plant species, *Deschampsia cespitosa*, forthe unidentified *Poaceae*, and for the plant genera, *Carex spp*. Faecal samples taken during the summer had a higher percentage of *Deschampsia cespitosa* and *Poaceae* compared to samples taken in autumn and the percentages were 6.3% and 5.9% higher, respectively. *Carex spp* showed an opposite result, with 4.4% lower percentage in summer compared to autumn samples. The interaction between study area and season was significant for *Avenlla flexuosa* (P< 0.001) and *Festuca rubra* (P< 0.01) whereas the interaction between season and reproductive state was only significant (P< 0.05) for *Festuca rubra*

(Table 5). When analyzing two study areas separately, no significant effect of season was observed in the high stocking density area. In the area with low stocking density, there were more fragments of *Avenlla flexuosa* in the faecal samples of cattle observed in autumn (43.7% ± 11.7) than those observed in summer (28.3% ± 10.2). Conversely, fewer fragments of *Festuca rubra* were identified in the faecal samples of cattle in autumn (4.5% ± 3.1) compared to those in summer (8.0% ± 2.7).

The reproductive states had no significant effects on any of the plant species or plant genera, but had tendencies of significances for *Avenlla flexuosa* (P= 0.089) and *Festuca rubra* (P= 0.098). The interaction between study area and reproductive states was only significant (P<0.01) for *Avenella flexuosa*. In the area with low grazing density, dry cows (39.0% ± 14.1) had higher intakes of *Avenella flexuosa* than lactating cows (32.5% ± 12.1). Conversely, in the area with high stocking density, lactating cows (21.0% ± 9.1) had higher intakes of *Avenella flexuosa* than dry cattle (15.6% ± 7.3) (Figure 6).

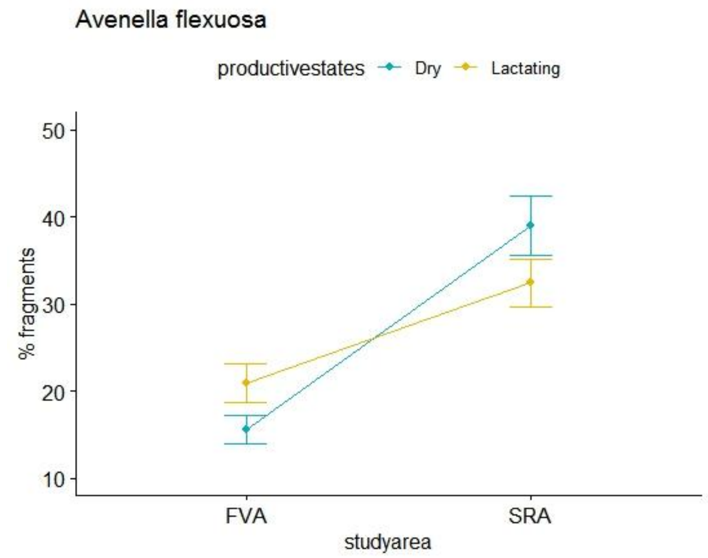

Figure 6. Mean values of the observed proportions of fragments of *Avenella flexuosa* in faecal samples by lactating and dry cattle in study areas of high (FVA) and low (SRA) stocking densities.

Table 5. Coefficient estimates, 95% confidence intervals (CI) and standard errors (SE) of the best-ranked linear models describing the variation in fragments of plant species and plant genera in the faecal samples (*: interactions between two variables).

Model		Estimate	CI (2.5%-97.5%)	SE
Avenella flexuosa	Intercept	15.57	(10.69, 20.46)	2.45
	Season (summer)	0.13	(-6.02, 6.29)	3.08
	Study area (SRA)	31.56	(24.10, 39.03)	3.74
	Reproductive states(lactating)	5.34	(-0.84, 11.52)	3.10
	Study area (SRA) * Reproductive states(lactating)	-11.90	(-20.72, -3.09)	4.42
	Study area (SRA) * Season (summer)	-15.56	(-24.35, -6.76)	4.41
Deschampsia cespitosa	Intercept	29.17	(25.96, 32.39)	1.61
	Season (summer)	6.25	(2.43, 10.07)	1.91
	Study area (SRA)	-13.13	(-16.95, -9.32)	1.92
Carex spp.	Intercept	16.48	(14.10, 18.86)	1.19
	Season (summer)	-4.35	(-7.18, -1.53)	1.42
	Study area (SRA)	-6.56	(-9.36, -3.74)	1.42
Poaceae	Intercept	5.66	(4.89, 6.44)	0.39
	Season (summer)	5.93	(4.83, 7.03)	0.55
Festuca Rubra	Intercept	5.56	(4.30, 6.82)	0.63
	Season (summer)	-1.08	(-2.96, 0.79)	0.94
	Study area (SRA)	-0.35	(-1.96, 1.26)	0.81
	Reproductive states(lactating)	-1.35	(-2.96, 0.26)	0.81
	Study area (SRA)* Season (summer)	3.21	(0.95, 5.47)	1.13
	Season (summer) * Reproductive states (lactating)	2.55	(0.29, 4.82)	1.13

4. DISCUSSION

This study aimed at finding patterns in cattle's plant intake when grazing on the boreal forest pastures (SNA and FVA) in Norway with different stocking densities and for cattle with different energy requirements (lactating and dry cows). The first hypothesis was partly supported, namely that lactating cattle due to its milk production have a higher energy requirement than dry cattle, and therefore graze more on grass species than dry cattle in the high stocking density pasture but the grass intakes of both lactating and dry cow were similar in the low stocking density pasture. The second hypothesis was confirmed, namely that cattle in the low stocking density area prioritize to eat grasses and especially *Avenella flexuosa*, while cattle in the high stocking density area graze on other plant spices, as *Carex spp*.

The overall picture was although more complicated. An interaction between reproductive states and study area was detected for the intakes of grass species, showing that lactating cows graze nearly the same percentages of grass species in both study area while dry cows graze significantly less grass species in the high stocking density area than in the low stocking density area (see Figure 3). The only observed plant species that gives an answer to the differences on the grass species intakes of lactating and dry cows in the high stocking density area is *Avenella flexuosa* (Figure 6). The results clearly illustrated that lactating cow keep on grazing this grass species, even on forest pastures with a high livestock density, like in FVA. *Avenella flexuosa* is known to have a high energy value compared to other plants commonly found on unimproved pastures in Norway and the species keeps its energy value even into early autumn (Lunnan & Todnem, 2011). The results showed that *Avenella flexuosa* intake differed between lactating and dry cattle in the high livestock density area and this maybe due to that lactating cows with energy requirements for lactations are more selective than dry cows in an intensively grazed area (Farruggia et al., 2006). Therefore, lactating cows graze more on grass with high-energy values, as *Avenella flexuosa*, to satisfy their lactation requirements compared with dry cows when grazing on intensive and poor pasture as FVA. The effects of reproductive state and interaction between study area and reproductive states were also significant for total deciduous species (Figure 4). While lactating cows graze less deciduous species in the high grazing density area compared to what they do in the low stocking density area, dry cow keep grazing same percentage of deciduous species in both areas. The differences could also explain that, in the area with high stocking density, lactating cow shift their intake from deciduous species to grass species in order to meet their high energy requirements when dry cattle maintain grazing on more deciduous species which provide relatively lower energy values. The importance of grazing for energy requirements for lactation can be underlined by the following: “Lactating cows could be able to increase their grazing time and/or their intake rate compared with dry cows, to maintain daily intake” (Farruggia et al., 2006). An increasing grazing time may also gives the answer to how lactating beef cattle can graze the same percentages of grass species when grazing on areas with a high livestock density compared to low density pastures. The reason for why dry cows graze more of the deciduous (and less grass species) on forest pastures with the high stocking density could be that there were more of other species (such as sedges species) available and that lactating cattle already have eaten the plants of the higher digestibility.

The results from this study showed that there were significant differences between plant intakes of beef cattle in the high and low stocking density areas. The effects were significant for both total grass and total sedges groups (Figure 2), showing that cattle in the area with low stocking density grazed more on grass species than those in the high stocking density area, while cattle grazed more sedges species in the high grazing density area in contrast to cattle in the low stocking density area. The three single species that could give the explanations for the differences in grass and sedges intakes are *Carex spp, Avenella flexuosa* and *Deschampsia caespitosa. Avenella flexuosa* is a typical grass species that grow on clear-cuts and on drier soils (Scurfield, 1954). Therefore, this species was grazed more in the low stocking density area, which also was dry area. Sedges species, as *Carex spp*, and grass species as *Deschampsia caespitose*, which are more common in wet areas (Anna Hessle et al., 2008) were grazed more in the high stocking density area that also was the wet area of the two. These results could indicate that plant intake of beef cattle is largely affected by the area in which they graze. As cattle are generally less selective grazers than other livestock (Fraser et al., 2009) and have great amount of plant intakes, they have a great proportion of intake from the plant which is common in where they graze. This is not surprising, but perhaps a more interesting interpretation is that lactating cows keeps more to the clear-cuts and avoid the wet areas even more than the dry cows, as lactating cows grazed more *Avenella flexuosa* and less *Carex spp* than dry cows in the same more wet area with the high stocking density.

Results from this study (Table 3) also detected very little amounts of coniferous species intakes for both lactating and dry cattle. It means that the damages of beef cattle are regarded as minor on the commercial coniferous forest of Norway spruce (*Picea abies*). This is because cattle are reluctant grazing on such conifer trees (Wehn et al., 2011), or they are grazed in very small amount by accident when grazing on other species. This result may be considered as a positive for establishments of new generations of spruce trees, since cattle leave these forest plants but rather graze grass, deciduous and other plants that compete with spruce seedling for light, water and nutrients.

The described differences in plant intake of beef cattle in different reproductive states should be taken into considerations when managing unimproved forest pastures. The value of open pastures with grasses such as *Avenella flexuosa* is important to recognize, and especially when using lactating cattle in areas with high stocking densities (Sæther et al., 2006). However, the damages of grazing cattle on deciduous trees seem to higher when using dry cattle in an unimproved land with high grazing density. Therefore, when applying beef cattle in unimproved clear-cut forest pastures with high grazing density, it is valuable to use more lactating cattle, as the effects of lactating cattle on deciduous forest are lower than that of dry cattle. However, there were no significant grass intake differences between lactating and dry cows in the forest pasture with low grazing density so that the effects of applying both lactating and dry cows on the pasture are similar. The result from the plant intake inferences for lactating and dry beef cattle should be applicable for other cattle breeds like dairy cattle (Gibb, Huckle, Nuthall, & Rook, 1999) but also non-ruminant herbivores like mares (Farruggia et al., 2006; Lamoot, Vandenberghe, Bauwens, & Hoffmann, 2005), showing that within a species, individuals with requirements for lactation have higher intakes of plants with high energy values compared to other individuals when grazing in areas with high stocking densities.

5. CONCLUSION

The current study investigated plant intakes of lactating and dry cattle when grazing on two boreal forest pastures with different grazing densities. One important result was that lactating beef cows with energy requirements graze more on grasses with high-energy values, like *Avenella flexuosa*, compared to dry beef cows without the same requirements. The result became clear when grazing in forests pastures with high stocking densities, but in a pasture with low grazing densities, the pattern was not that clear as intakes of grass species for both lactating and dry cattle were similar. The nature of the area and what species that grows there certainly influence the result. In general, cattle in the low stocking density grazed more on *Avenella flexuosa*, a species that is common in more dry boreal pastures, compared to cattle in the high stocking density area, which was a more wet area and where the cattle more grazed on *Carex spp* and *Deschampsia caespitosa,* which are known to be more common in wet areas. The results also confirmed that cattle seldom eat needle tree plants like Norway spruce (*Picea abies*) but prefer to graze on the grasses commonly found on clear-cuts during the establishment of a new forest generation, which is a good result for forest managers as for cattle farmers. Furthermore, the results could be used to select beef cattle with different reproductive states when using various forest pastures. The use of cattle influences the ecosystem and the forest regeneration but also the overall productivity of such unimproved lands in Norway. The agriculture ministry pointed out that “importance should be given to knowledge-based utilization of resources in unimproved lands, encouraging efficient land use, focusing on quality production and profitability to a greater extent, and increasing emphasis on the synergy between grazing and other social considerations” ("Landbruks-og matedeparteentet,,," 2011). Therefore, continuous investigations of unimproved land quality, body conditions of grazing cattle, productivities of grazing systems and the biodiversity of unimproved lands are highly required when managing unimproved pastures. These investigations would provide a strong scientific background for farmers and managers to be able to make an economically and ecologically valuable management strategy in boreal forest pastures.

Acknowledgements

I would like to express my sincere gratitude to my supervisor Morten Tofastrud for the support, patience, motivation and guidance on both statistical and written parts of my thesis. I like to thank Fred Håkon Johnsen and Elisabeth Røe for the guidance and support on the topic selection of my master thesis. I also sincerely appreciate to Svein Øivind Solberg for the help to editions and comments on my thesis.

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