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A4 Development of an adaptive multi paddock grazing suitable for Estonian climate conditions

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Goal: To develop an adaptive multi-paddock grazing (AMPG) methodology suitable for Estonian climate conditions and to evaluate the effect of this grazing method on the qualitative and quantitative yield of permanent grasslands.

Literature review of adaptive multi paddock grazing systems

Purpose: Adaptive multi-paddock grazing (AMPG) has shown to be able to increase pasture productivity and in turn both animal performance and the economic performance of livestock farms. This method of grazing management is currently implemented on more than 21 million hectares of pastures across the world. Although seeing rapid adoption across in many countries, experiences with AMPG remain limited in Estonian conditions. Towards that end this activity strives to gather insights from research papers, literature and publications to inform what optimal AMPG management in Estonia conditions would look like.

Evaluation: The goals of this innovation activity were fully achieved.

The actions carried out within A 4 were:
A literature review based on research papers, literature and publications in English, as well as consultations with foreign experts.
Based on this review an overview of the field of AMPG grazing was prepared, including examples of experiences to Estonia climatic conditions to develop insights into Estonian *adaptive multi-paddock grazing* (e AMPG).
A preliminary AMPG system was planned for the paddocks of 2 participating Estonian farms in the project, resulting in a diagram of the movement of animals in the paddock.

Literature review on the species composition of pastures for beef cattle

What was done

Based on research papers, literature and publications in English, as well as consultations with foreign experts, an overview of the field of AMPG grazing was prepared, including examples of experiences in similar conditions as the Estonian climate. This review was prepared by the Estonian University of Life Sciences, Institute of Agriculture and Environment (Kadri Tali, Katrin Heinsoo).

Results (summary)

Large wild ungulates and later livestock have been the main shapers and keepers of open landscapes in Estonia. As such, plant and livestock communities have developed mutually beneficial relationships to survive. The most direct expression of this is that grasses need to be grazed to survive, without it open meadows will transition into woodlands, and the rich diversity of meadow species will make place for early pioneer forest species. Studying this coevolution has revealed that grazing systems that best imitate native herd migrations also have the least harmful effects on pasture vegetation (Danckwerts et al. 1993).

Different grazing methods have differing impacts on the species richness, species composition, soil fertility, soil density, carbon sequestration, etc. of the grazed areas. Pastures in good condition are more productive, more stable and more resilient to environmental change than depleted or degraded areas. At the same time they provide both more ecosystem services and a better service to the farmer.

There are two main ways of grazing, being continuous grazing and rotational grazing, with the latter having varying strategies. Grazing management needs to be adapted to the pasture types, and management capacities of the farm. To promote and maintain healthy pastures, rotational grazing is always preferred. This is also advised in the management plans for Estonian semi-natural habits, however in practice almost all such areas are under continuous grazing.
The scientific name for a rotational grazing strategy that is adapted to the growth of forages during the season is adaptive multi-paddock grazing (AMPG). In farming communities this type of grazing has different names such as holistic managed grazing, grazing naturally or mob grazing. The core principles of AMPG are having multiple paddocks, moving cattle regularly, matching stocking rate to available forage dynamically during the year, ensuring adequate grazing pressure and respecting the recovery times of the plants.

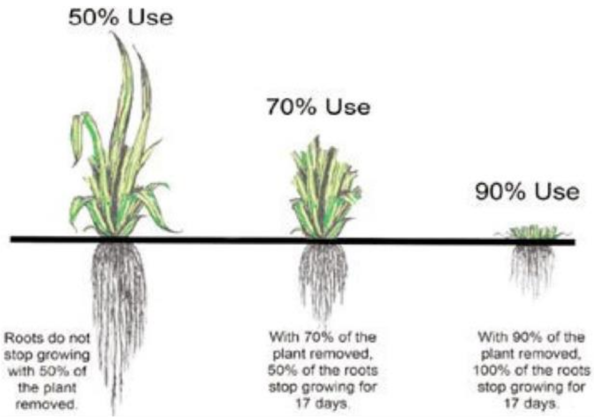
Key concepts in APMG are preventing overgrazing, which is grazing a plant before it has fully recovered during the growing season, and preventing overresting, which is a lack of grazing that allows pasture to transition to young forests. Both reduce pasture quality. Through overgrazing plants lack the necessary recovery period to restore nutrient reserves in the root, leading to reduced vigour and ultimately disappearance of that plant from the pasture. With overresting the pasture community transitions away from forage species towards woody species, as such reducing the overall amount of forage available.

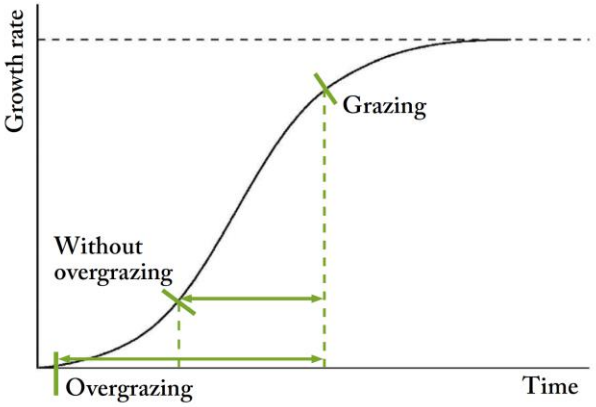
Pastoralists using AMPG have a large number of paddocks (16-30), usually created with mobile electric fencing. Once grass is grazed it will generally start growing back after 3 days. As such livestock ideally never stays longer than 3 days in one paddock to prevent overgrazing. Recovery periods can vary anywhere from 30 to 90 days (Teague et al., 2011). Given a high quality of pasture, long hours of sunshine, adequate moisture and adequate temperatures, pastures in Estonia can even recover in 20 days during spring. The recovery time depends largely on the intensity of the grazing - the more the plant has been eaten, the more time is needed for its recovery. Other key elements are plant species composition in the pasture, climate and weather.

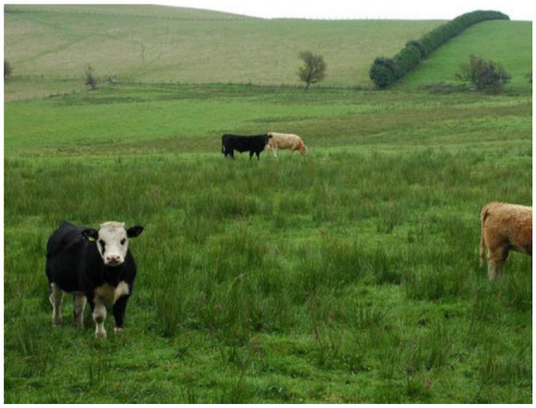
Grazing density, which is the amount of livestock units per area of fodder, in AMPG systems is often higher compared to continuous grazing. A study by Norton (1998) reviewed grazing loads ranging from 40-200% of recommended levels, but detected no negative ecological impacts as long as recovery periods were respected. Such high density mimics the natural phenomenon of large herds of grazers which move bunched together through the landscape under the pressure of predators. The short stay of the animals compared in higher densities has several advantages compared to continuous grazing: (1) reduces selectivity, the tastier plants are not eaten as much; (2) a smaller portion of one plant is eaten in a short period; (3) food is distributed more evenly across the landscape.

By reducing selectivity, species are prevented from being overgrazed and thus disappearing from the pasture, which reduces its biodiversity. A reduced biodiversity in turn reduces pasture productivity. The 30 year biodiversity trials at Jena in Germany, have shown a linear relationship between increased biodiversity and productivity in grasslands. A high biodiverse pasture can produce the same amount of biomass compared to a high fertilized (200 kg/N/y) monoculture pasture (Weigelt et al. 2009; Weisser et al. 2017).

By eating a smaller portion of one plant, more leaf area is left to help recover the plant while less plant roots are removed as a consequence of reducing the leaf area. To optimize pasture productivity, AMPG grazing systems can be implemented where livestock are moved before eating more than 50% of the biomass. In this case, grasses don’t remove any of their roots and thus recover much quicker. Such systems have been shown to produce 42% more feed in a growing season compared to overgrazing or cutting the pastures. The goal is to keep plants in a fast growing vegetative phase, preventing the slow growth associated with intense defoliation or the transition to a reproductive phase. This increased biomass leads to more photosynthesis, deeper roots, more carbon sequestered, more energy in the plant and thus higher average daily gains (Nunes et al. 2019; Jones 2018).







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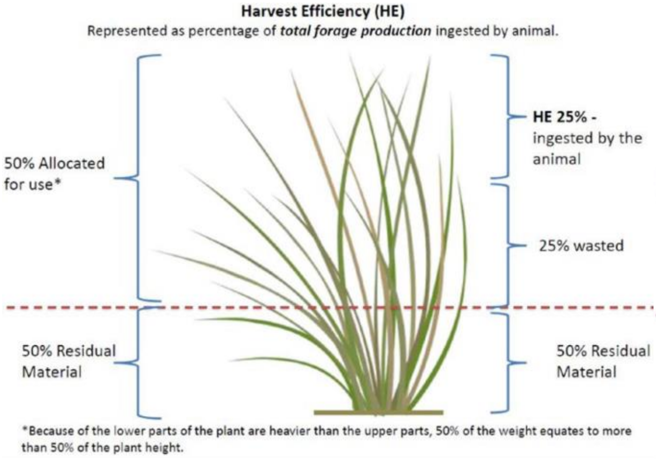
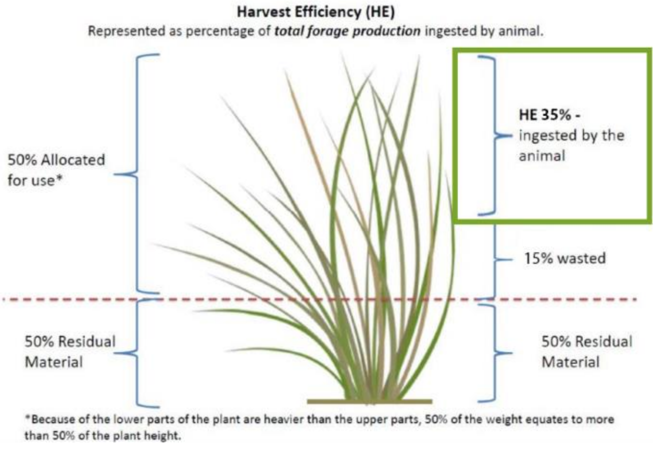
Low stocking density results in patchy grassland, overgrazing of areas and with low diversity
Higher stocking densities result in even grazing pressure and more species diversity in pastures





A higher grazing pressure also makes sure that more feed is actually ingested by the livestock. The harvest efficiency, which is the percentage of the total forage available ingested by livestock, increased from 25 - 35 % in a high density grazing scenario. This increase is due to less forage being wasted due to the increased competition for feed (Green and Brazee 2012; Marts et al. 1999). Stocking density should always be based on the amount of forage available in a pasture, while also taking into account other environmental factors such as the moisture levels of the soils. During a very wet period a high stocking density might cause significant damage to a pasture, which can negatively affect pasture productivity in the following years.

Another consideration to take into account when planning grazing is the digestibility of the forage. The digestibility is highest for actively growing forage in its vegetative state and declines progressively as the plants mature going through its reproductive phase and ultimately senescence. This is also reflected in research that has shown that in continuous grazing systems animals only use a part of the forage potential of the pasture seeing the overrested plants often grow too old and lose their nutritional value and taste. Semi-natural habitats are particularly sensitive in this regard. In temperate climates, forage matures and ages quickly. As such, excessively long rest periods or a low grazing load causes a decrease in forage quality.

Livestock learn to optimize their feed intake based on their past experiences (Provenza et al., 2003). If they are used to eating only a small portion of the tastiest grasses, they will not experience the health benefits of a more varied diet, and the herd will not use the full potential of the pasture (Manteca et al., 2008). As selective grazing also changes the composition of pasture grass, this further reduces the ability of livestock to get to know plants that are useful and necessary for them at different times. Through AMPG, livestock is encouraged to sample the entire range of species available in the pasture, increasing their ability to learn to use less palatable but healthy species and avoid toxic ones. Many farmers believe this behavioural change is impossible; however research clearly shows that animals can learn to eat previously unknown plants (Villalba et al., 2006). During the familiarization period, it is important to observe and manage the animals more carefully, as an initial decrease in animal growth is likely until the herd learns to eat in a new and more diverse way. Such an adaptation period can last up to three years, depending on the animal species, the type of animals (young animals, mothers with offspring, etc.) and herd size (Provenza 2003).

About 2/3 of global soil carbon is stored as soil organic carbon and the rest as inorganic carbon. Soil organic carbon (SOC) is influenced by environmental conditions (moisture, precipitation, vegetation type) and human activity. As such, management is an important factor deciding if soil acts as a carbon binder or as a source of volatile carbon dioxide (CO2) in the atmosphere. Soil organic carbon can be broadly divided into labile and stable states. Labile organic carbon is easily degradable organic matter, which is easily broken down by microbes. One of the final products of this decomposition process of organic matter is CO2. At the same time, it is labile carbon that increases the number of microbes in the soil, which in turn leads to a better supply of both nutrients and air to the plant roots. A larger amount of labile carbon is important both for the reducing pasture compaction and the increasing plant biomass production. Semi-natural grasslands in humid regions are highly sensitive to environmental changes (including water content, temperature, nutrient regime and microbial activity), where even small increases in soil organic matter decomposition rates can result in large carbon fluxes back to the atmosphere. (Mitra et al., 2005).

Overgrazing often leads to erosion and damage to the sward which decreases labile soil carbon stocks and releases CO2. Overresting reduces the production potential of the pasture, thus leading to lower levels of photosynthesis and less carbon sequestered. Through AMPG practices, sequestration rates of between 1.76 - 13.17 t CO2/ha/yr have been reported. This large gap is due to a large variability in management, climate, soils and plant species. The GHG intensity of livestock farming is an active topic. To adequately examine this, the entire livestock system must be considered as a whole and not focused only on the CH4 from enteric fermentation. Key in this are both the carbon sequestration rates of pastures and the photooxidation of the evapotranspiration of pastures which creates hydroxyl radicals that actively remove CH4 and other pollutants in the atmosphere. Both these elements make it possible to move toward carbon neutral and even carbon negative livestock farming.

AMPG is not common practice in Estonia. Literature in Estonian is limited to manuals published in the 1970s and 1980s. Earlier rotational grazing experiments were carried out on cultivated pastures, and there are currently no research studies on grazing on semi-natural grasslands under Estonian climate conditions. Pasture quality can vary significantly in semi-natural grasslands, with yield in swampy grasslands with poor species ranging between 3-20 t/ha, while floodplain grasslands can have yields between 14-70 t/ha. Rotational grazing has been mentioned or recommended by almost all governmental management plans concerning potentially grazed communities in Estonia. However, in reality it is not practiced on a large scale in Estonia.

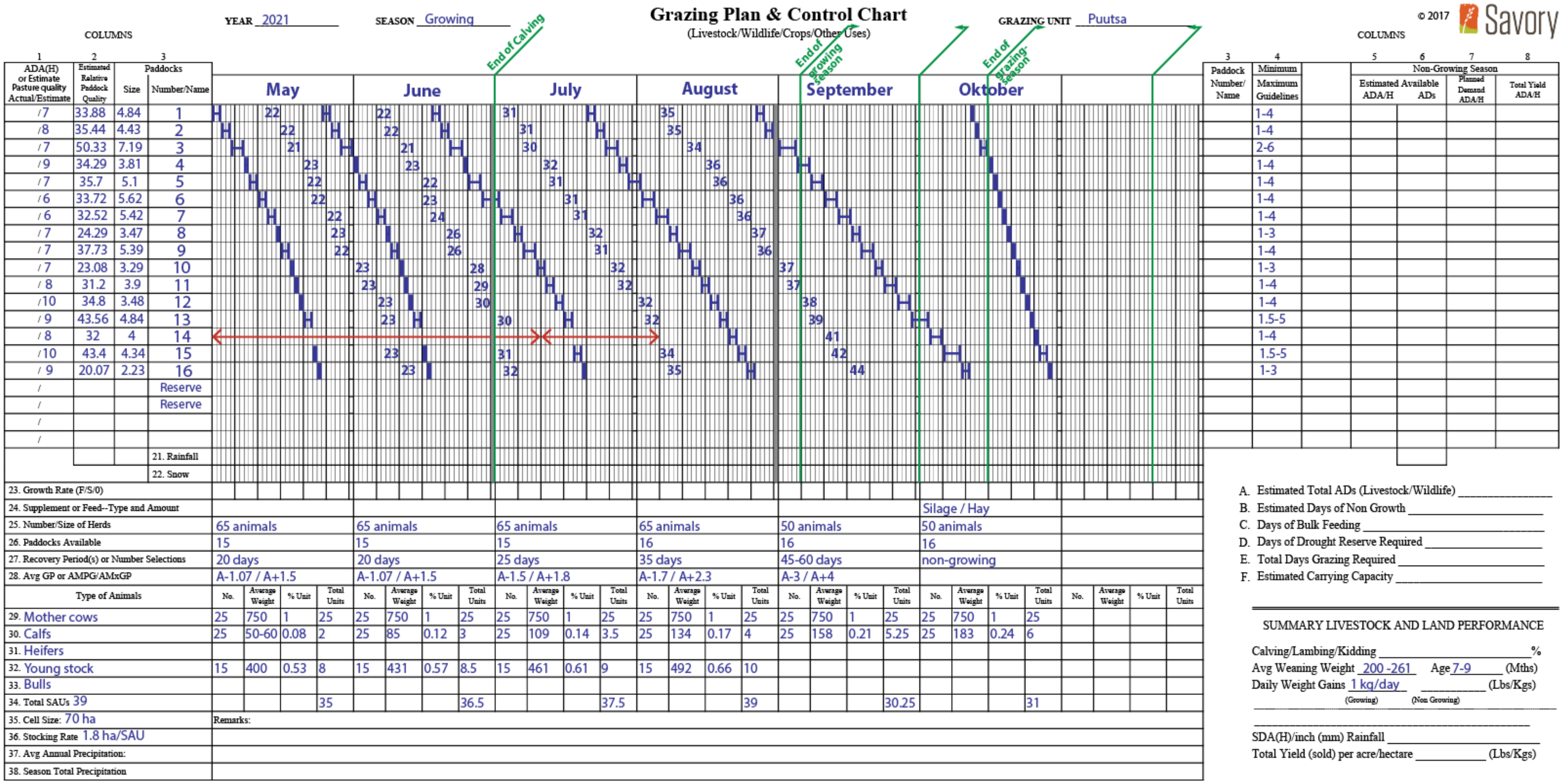
As a summary, the key recurring themes in AMPG systems revolve around preventing overgrazing and overresting. Both have a negative impact on pasture productivity and forage quality and thus limit the production capacity of livestock farmers. Key in preventing both, is managing the livestock adaptively throughout the growing season, matching the amount of livestock with the amount of forage available, keeping environmental considerations into account such as the moisture levels of the soils and most importantly respecting the recovery period of the plant after grazing.

Example of grazing scheme

To illustrate an AMPG system, an example grazing map and grazing chart have been included in the report. The grazing chart used on that of the Savory Institute, which actively helps farmers implement Holistic Management on 21 million hectares across the world. This grazing chart is set-up for a grazing group of 65 animals from Puutsa talu on 70ha of land. The planned recovery days between grazing ranges from 22-44 days, with the grazing season starting in May and ending in October. This chart takes into account both the pasture size and pasture quality to plan how long livestock can stay in one paddock. When executing this grazing plan, the farmer would update the planned grazing as the season progresses, observing the forage availability and recovery rates continuously. As such, this grazing chart should not be copied and applied on any other farm.

Image 1. Grazing pattern

Table 1. Savory Holistic Grazing chart



Grazing Plan & Control Chart

(Livestock/Wildlife/Crops/Other Uses)

YEAR 2021

SEASON Growing

GRAZING UNIT Puutsa

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COLUMNS

1 ADA(H) or Estimate Pasture quality Actual/Estimate	2 Estimated Relative Paddock Quality	3 Paddocks Size	3 Paddocks Number/Name
/7	33.88	4.84	1
/8	35.44	4.43	2
/7	50.33	7.19	3
/9	34.29	3.81	4
/7	35.7	5.1	5
/6	33.72	5.62	6
/6	32.52	5.42	7
/7	24.29	3.47	8
/7	37.73	5.39	9
/7	23.08	3.29	10
/8	31.2	3.9	11
/10	34.8	3.48	12
/9	43.56	4.84	13
/8	32	4	14
/10	43.4	4.34	15
/9	20.07	2.23	16
/			Reserve
/			Reserve
/			
/			
			21. Rainfall
			22. Snow

	May	June	July	August	September	Oktober	
23. Growth Rate (F/S/0)							
24. Supplement or Feed--Type and Amount						Silage / Hay	
25. Number/Size of Herds	65 animals	65 animals	65 animals	65 animals	50 animals	50 animals	
26. Paddocks Available	15	15	15	16	16	16	
27. Recovery Period(s) or Number Selections	20 days	20 days	25 days	35 days	45-60 days	non-growing	
28. Avg GP or AMPG/AMxGP	A-1.07 / A+1.5	A-1.07 / A+1.5	A-1.5 / A+1.8	A-1.7 / A+2.3	A-3 / A+4		

Type of Animals	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units	No.	Average Weight	% Unit	Total Units
29. Mother cows	25	750	1	25	25	750	1	25	25	750	1	25	25	750	1	25	25	750	1	25	25	750	1	25				
30. Calfs	25	50-60	0.08	2	25	85	0.12	3	25	109	0.14	3.5	25	134	0.17	4	25	158	0.21	5.25	25	183	0.24	6				
31. Heifers																												
32. Young stock	15	400	0.53	8	15	431	0.57	8.5	15	461	0.61	9	15	492	0.66	10												
33. Bulls																												
34. Total SAUs 39				35				36.5				37.5				39				30.25				31				

35. Cell Size: 70 ha

36. Stocking Rate 1.8 ha/SAU

37. Avg Annual Precipitation:

38. Season Total Precipitation

Remarks:

3 Paddock Number/ Name	4 Minimum Maximum Guidelines		5 Non-Growing Season Estimated Available ADA/H	6 Non-Growing Season Estimated Available ADs	7 Planned Demand ADA/H	8 Total Yield ADA/H
	1-4					
	1-4					
	2-6					
	1-4					
	1-4					
	1-4					
	1-4					
	1-3					
	1-4					
	1-3					
	1-4					
	1-4					
	1.5-5					
	1-4					
	1.5-5					
	1-3					

A. Estimated Total ADs (Livestock/Wildlife) ____________
B. Estimated Days of Non Growth ____________
C. Days of Bulk Feeding ____________
D. Days of Drought Reserve Required ____________
E. Total Days Grazing Required ____________
F. Estimated Carrying Capacity ____________

SUMMARY LIVESTOCK AND LAND PERFORMANCE

Calving/Lambing/Kidding ____________%
Avg Weaning Weight 200 -261 Age 7-9 (Mths)
Daily Weight Gains 1 kg/day (Growing) ____________ (Non Growing) (Lbs/Kgs)
SDA(H)/inch (mm) Rainfall ____________
Total Yield (sold) per acre/hectare ____________ (Lbs/Kgs)

Development of an adaptive multi-paddock grazing system suitable for Estonian conditions - Field testing

What was done

This activity strived to adapt the concept of *adaptive multi-paddock grazing* to Estonian conditions (e-AMPG) through grazing experiments and drawing up guidelines for implementing the e-AMPG grazing system in production. In the course of the activity, grazing with different loads and different time frames was planned in the paddocks of three farms in order to find out which loads are optimal for managing semi-natural meadows over a long period of time in such a way as to maximize yield, maintain soil structure and achieve good animal growth.

The positions and sizes of the paddocks and the movement patterns of the animals were defined in the landscape and control areas were demarcated in order to evaluate the changes of various factors during the course of the experiment. In the areas, a list of plant species was compiled, biomass analyzes were collected, the coverage of species and species groups, the chemical composition of grass fodder (NDF, hemicellulose, crude protein, metabolizable energy (ME), relative feed value (RFV), all these parameters were analyzed using the AOAC method in the EMU plant biochemistry laboratory) and soil density (EMU PKI soil laboratory).

The impact of grazing (treatments: ungrazed, normal, short-term high-load grazing) was evaluated in five areas between autumn 2019 and autumn 2020 by collecting soil samples from the 0-20 cm layer three times: autumn 2019 (after the end of the grazing period) and 2020 in the spring (before the start of the grazing period) and in the autumn (after the end of the grazing period) of the year. Two research areas (Senta 1 and Senta 2) were located on the lands of Sentafarm and three (Puurmani 1, Puurmani 2, Puurmani 3) on the lands of Airi Külvet FIE. Senta 1 and 2 sites were sampled from 5 points per transect, and Puurman sites 1, 2 and 3 were sampled from 4 points per transect. Taheva farm was part of the experiment in the first year but was replaced by Airi Külvet FIE in the second year. Earthworms were also collected and determined from the soil samples. The total activity (BA) and microbial respiration (SIR) of the soil microbial community were also measured.

The intermediate reports were compiled by the Estonian University of Life Sciences, Institute of Agriculture and Environment (Kadri Tali, Katrin Heinsoo).

Results (summary)

Insight of the first year

The average biomass yield of the semi-natural pastures of Sentafarm were 4 t/ha for the continuous grazing control area and 8 t/ha for the AMPG experiment area. This enables to graze these areas with a higher animal load of 1 SLU/ha. As 2018 was an exceptionally dry year, the average biomass numbers are relatively low and are expected to be significantly higher in normal years. Another key finding was that the autumn crude protein content was higher in the AMPG area. Based on the experience in the first year the grazing plan for the following year was adapted, mainly with higher animal numbers to ensure a better grazing density.

Insights of the second year

The findings of the first year of the study were further solidified in the second year, with the AMPG grazing system showing increased nutritional value of the feed and allowing higher animal loads than have been used in these areas so far.

Plant species, biomass and coverage of species groups

Plant species analysis in the test areas showed that the most species-rich paddocks are located in the Pedja meadows (Puurmani 1,2 and 3), the poorest the Mustjõgi test meadows (Senta 1 and 2), and the Vaidva meadows (Taheva) was between them in terms of diversity. Grasses, sedges, legumes and other grasses were separated from the hand samples collected once a month during the grazing period, dried and weighed. These four species groups were selected for analysis because of their different feed values and palatability. Under continuous grazing, tall grasses and sedges would not be grazed as much and thus be more dominant in the long run. Under AMPG one would expect more even grazing, and thus a less dominance of such species.

As could be expected, the number and composition of species did not change statistically significantly during such a three-year experiment, although it could probably be done over a longer period. However, empirically one could notice a decrease in the coverage of sedges and buttercups in the paddocks of Sentafarm, which participated in the experiment the longest. Seasonal changes in coverage are presented in Figure 1.

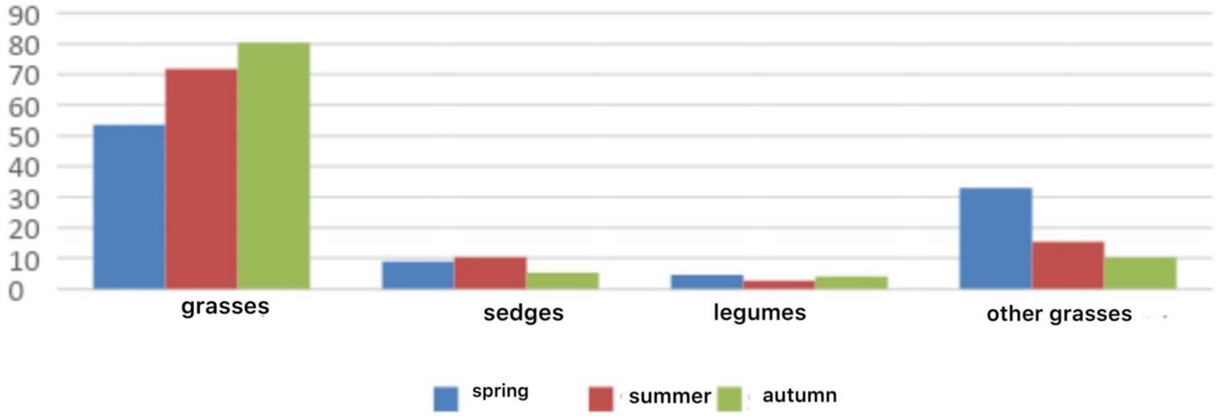

Figure 1. Biomass dynamics of four species groups during the grazing period

Chemical composition of forage

All indicators of forage value and biomass growth were lowest in mid-summer in both control and AMPG areas. By autumn, the forage value indicators became different in the AMPG and control areas due to the growth of young plant shoots (Figure 2). AMPG grazing had a visible advantage compared to conventional extensive grazing – fiber content decreased, crude protein increased, metabolisable energy increased, dry matter digestibility increased and relative feed value increased.

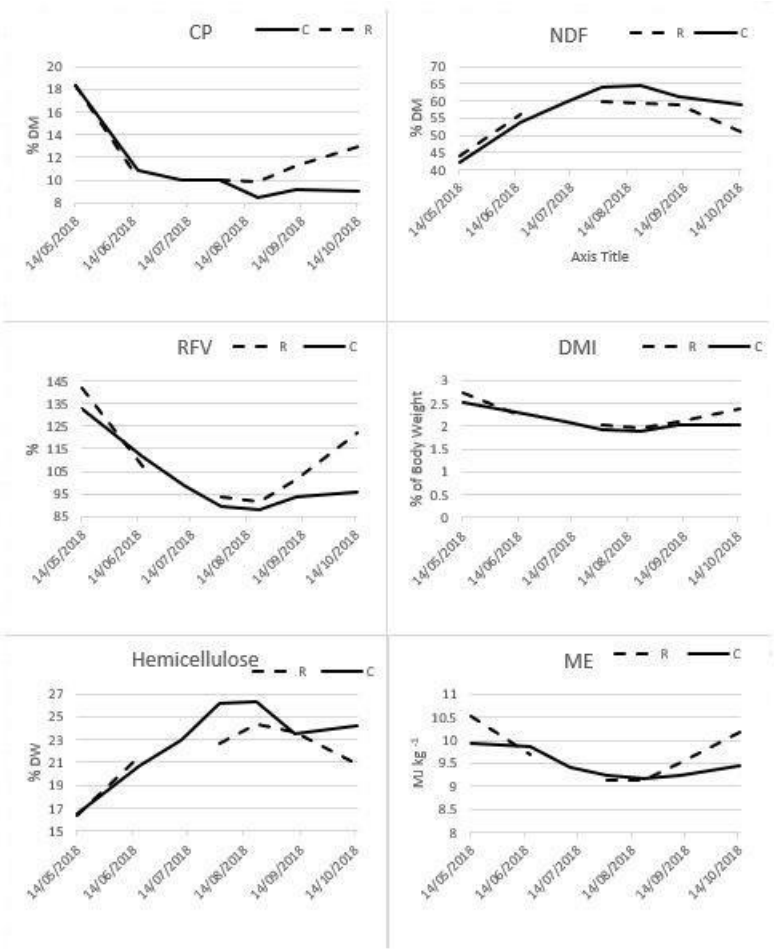

Figure 2. Indicators of crude protein (CP), neutral detergent fiber (NDF), relative feed value (RFV), dry matter digestibility (DMI), hemicellulose and metabolizable energy (ME) during the vegetation period.

Soil density (EMU PKI soil laboratory)

The main indicator, according to which the load of grazing was evaluated, was the density of the soil at a depth of 5-10 cm. As a result of grazing, the soil can become compacted, which manifests itself in a higher value of bulk density (Xie & Witting, 2004). In this study, the effect of grazing on soil compaction was rather positive (Figure 1), and soil compaction did not occur as a result of grazing.

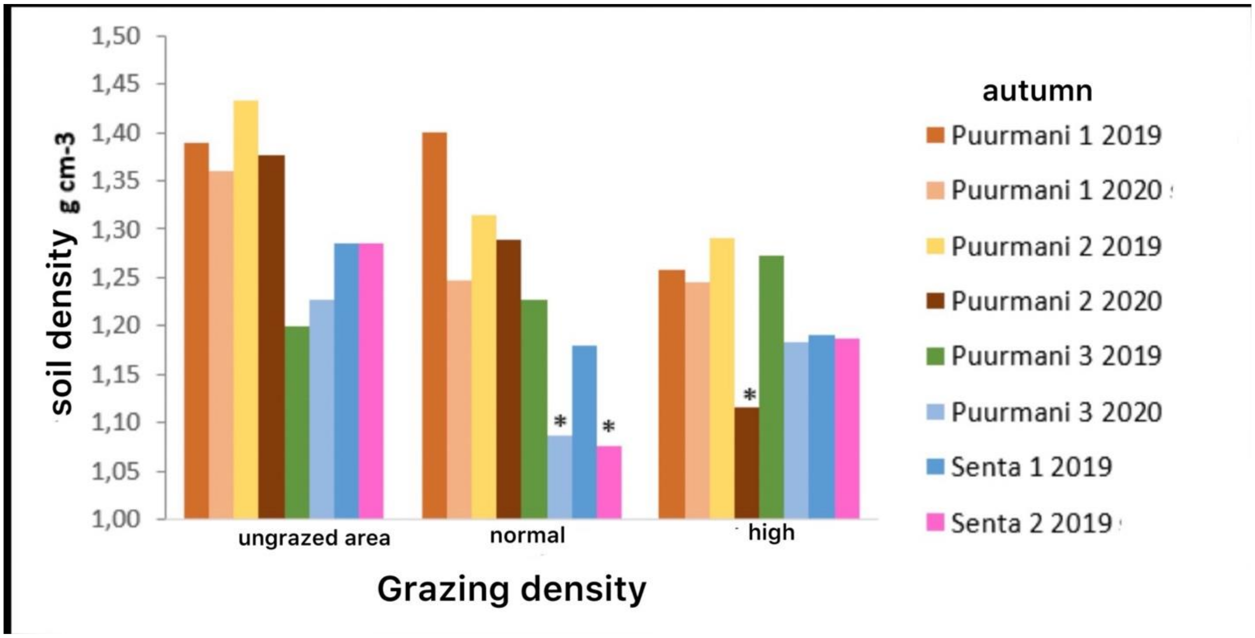

Figure 1. Autumn soil densities, determined at the end of grazing periods in the study areas. * indicates a statistically significant difference ($p<0.05$) compared to the ungrazed area at one sampling time within one area.

Changes in soil organic matter happens over long period of time, and therefore clear trends in soil C and N contents depending on grazing load were not detected within the scope of this study The soil of the research areas was characterized by a humus horizon varying between 25-60 cm and a high C content (2.35-6.91% C).

The plant available phosphorus (P) and potassium (K) content in the soil in all study areas were poor. During grazing, animals return part of the nutrients removed by biomass back to the grassland as excrement. In this study this was not sufficient to increase the content in the soil. The contents of P and K absorbed by plants increased slightly as a result of grazing in areas Puurmani 1 and 3, but in areas Puurmani 2, Senta 1 and 2 the contents decreased. Soil pH remained stable in all areas. More extensive soil testing is necessary to gain insights into these dynamics as the level of availability of soil nutrients to plants is influenced by a range of factors including soil microbiology, plant species composition, soil temperature, soil moisture, soil pH, soil gas exchange and soil type. As such, no adequate insights could be generated on this topic.

In terms of earthworm species, common earthworm (LTER), gray worm- *Aporrectodea caliginosa* (ACAL) and Black-headed Worm (ALON) were statistically more abundant in the Puurman sample sites than in the Senta sample sites. On the other hand, the species octagonal cutworm (DOCT) and milky marsh worm (OLAC) were more numerous in the Senta sample sites. In addition, the weight (g) of earthworms per m2 and the proportion of anetic species were statistically reliably higher in Puurmani.

The biomass and activity of the soil microbial community is affected by both soil moisture and manure that reaches the soil during grazing. Although there were no reliable correlations in the data, there are still somewhat higher indicators of the microbial community (SIR, BA) in the paddocks with the highest grazing load. In order to find out the possible connection, the experiments in the areas should be continued significantly longer.

Conclusion

Compared to continuous grazing, which is currently dominant in Estonia, AMPG systems tested in Estonian conditions provide more biomass throughout the growing season, and more nutritious forage during the growing season. High grazing density did not cause undesirable changes to either the vegetation or the soil structure. The soil bulk density decreased after AMPG grazing, which is the opposite of what was expected. There was no effect of grazing on soil C and N content, which is to be expected seeing a longer research period is needed to detect changes in these indicators. Some (statistically unreliable) increases in microbial activity were observed which may be caused by short term grazing at high loads under the AMPG system. No reliable insight could be created in regards to phosphorus and potassium levels, while pH remained unaffected by AMPG grazing.

In general, a 3 year study is considered too short of a time span to generate deep insights. During the project it was not possible to find out the short-term maximum load of grazing due to the lack of a sufficient number of animals. Although 3 years is not long enough to create good recommendations, it could be said that 20-30 days is a suitable rotation interval for semi-natural meadows in spring and early summer, even in dry summers. However, care has to be taken with such recommendations as they are in essence against the thought process behind AMPG> In AMPG constant monitoring of the situation is necessary and based on this monitoring shifts in the rotation of a few days are inevitable. As such, when planning AMPG systems an assumed recovery period can be used, however during the growing season farmers should only use this as a guideline and base the actual recovery period on the conditions in the field. Also there is a strong difference between pastures. Soils with different properties of different conditions such as temporary flooding, will respond differently to higher livestock loads. As such the situation must be closely monitored when starting out and the scheme we offer (Image 1) should not be followed rigidly but adapted to the conditions in each specific farm.

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