Supporting of cattle grazing in high nature value areas by virtual fencing technology

Golińska, B; Goliński, P

Poznań University of Life Sciences (PULS), Department of Grassland and Natural Landscape Sciences, Dojazd 11, 60-632 Poznań, Poland

Key words: grazing; high nature value areas; suckler cows; virtual fencing

Abstract

Evolution of virtual fencing designed for grazing beef cattle opens up new opportunities for available rangeland and grassland areas. Virtual fencing has the potential to reduce the amount of labour required for fencing, increase the flexibility of fencing to adapt to changing pasture conditions, improve precision and efficiency, and provide more options for grazing management. Taking into account this promising perspective, we have started the project ProEcoFarm which main objective is to produce top-quality culinary beef based on a model of farming suckler cows in a pasture-based feeding system on extensive grasslands located in high nature value areas using an Internet of Things (IoT) system. The experimental pasture is located in the Middle Odra Valley in Western Poland in the complex of semi-natural grasslands under protected area of Natura 2000. The study has been carried out from 2022. The grazed area of 27.5 ha is characterized by high diversification of botanical composition as a consequence of mosaic soil habitats of the pasture. We noticed occurrence of 48 species and 7 grass communities. Based on the monthly monitoring of the pasture during vegetation periods the biomass yield ranged from 0.8 to 2.7 t DM per ha, depending on the grass community. The study area is grazed by Limousine suckler cows by stocking density below 0.5 LU per ha. We conclude that for cattle grazing in high nature value areas the building of conventional fences are often impossible or/and not welcome. The remote control of the cattle herd using collar-mounted devices will make it possible to exclude areas with protected plant or animal species from grazing without building physical barriers. It is worth noting that an essential part of the technological innovation is determining grazing areas according to the cattle's feeding group classification.

Introduction

High quality culinary beef is obtained in pasture feeding conditions (Horn and Isselstein 2022). Young beef cattle are predisposed for this purpose, and above all the technology of suckler cows, from which weanlings are valuable slaughter raw material or can be further fattened to obtain a greater mass (Goliński et al. 2023). The use of pasture sward in the feeding of beef cattle has a very beneficial effect on the quality of meat (Daley et al. 2010; Stanton et al. 2018). Unlike feeding cattle with silage and concentrated feed, meat obtained from animals grazing on pasture has an increased content of unsaturated fatty acids, as well as minerals (O'Callaghan et al. 2016). In many countries in Europe and around the world, consumers are looking for this type of beef as a health-promoting food product ("green beef"). This aspect, as well as animal welfare, speaks in favour of greater use of pastures in animal husbandry, which has become one of the priorities in the agricultural policy of the European Union (Guyomard et

al. 2021). Pastures provide natural, valuable feed that is adapted to the digestive physiology of ruminants. Organizing effective feeding of pasture beef cattle is not easy, however it requires knowledge and material inputs. Current trends in the use of pastures consist in the application of innovative decision-support tools, mainly through grazing control using the IoT system (Internet of Things). Its key element is the use of virtual pasture fences (Anderson et al. 2014; Campbell et al. 2019; Goliński et al. 2023). Thanks to GPS technology and wave signal receivers mounted on the necks of animals, it is possible to use innovative technology for pasture feeding of cattle by controlling the herd for better planning and organization of grazing. The objective of the paper is to present the innovative technology of keeping suckler cows using the IoT system based on virtual fencing to control the herd for the purpose of extensive grazing of grasslands located in high nature value areas.

Methods

The study has been carried out from 2022 and is still running. The experimental pasture is located in the Middle Odra Valley (52º04' N, 14º97' E) near to Czarnowo village (Western Poland) in the complex of semi-natural grasslands under protected area of Natura 2000. Its character is of rangeland areas because no fertilization or other agricultural practices have been used there for many years. The grazed area of 27.5 ha is characterized by high diversification of botanical composition as a consequence of mosaic soil habitats of the pasture. The study area is grazed by Limousine suckler cows in the continuous grazing system by stocking density below 0.5 LU per ha (ranging during three year of the study from 0.37 to 0.46 LU per ha). Each year, at the end of the vegetation period, a cleaning cut was carried out to chop up the biomass residues after grazing. In the first stage of the study we assessed the sward yield and its nutritional value using the Crabbe et al. (2019) method. Samples were taken from the designated homogeneous pasture patches, where a 30 m × 30 m plot was randomly selected for in-situ ground measurements. The sward yield was determined using a quadrat frame method collecting biomass each three weeks during vegetation season from May to October. After cutting, the biomass was weighed, dried in the Binder chamber and subjected to laboratory analyses to assess the chemical composition of the sward (ash, crude protein, crude fat, crude fibre, NDF, ADF, β-carotene) using commonly applied methods. Additionally, the botanical composition of the sward using the Klapp method was estimated. Detailed studies of the sward, which constitutes the feed base for suckler cows, were necessary, because the supporting of cattle grazing is carried out on natural meadow complexes in the river valley, the characteristic feature of which is the diversity of plant cover and soil substrate determining the heterogeneous feed potential of the facility. In the next step, based on the collaboration with IT company within the ProEcoFarm project, the concept of supporting of cattle grazing in high nature value areas by virtual fencing technology was elaborated. The idea was to use our own materials and solutions that would make the system more accessible to Polish farmers, mainly from an economic point of view.

Results

Forage potential of the pasture

Studies on the botanical composition of the pasture sward revealed great diversity. In the sward of the analysed pasture, 48 species were recorded, including 11 grasses, 5 other monocotyledonous plants, 5 legumes and 27 other dicotyledonous herbs and weeds. Seven characteristic meadow communities were distinguished: No. 1/ *Poa pratensis-Festuca rubra*, No. 2/ *Alopecurus pratensis-Poa trivialis* with a significant share of legumes and dicotyledonous plants of moist habitats, No. 3/ *Alopecurus pratensis-Carex sp.* with a significant share of dicotyledonous plants of moist habitats, No. 4/ *Carex gracilis* community with a significant share of dicotyledonous plants of moist habitats, No. 5/ *Alopecurus pratensis-Agrostis stolonifera* with a significant share of dicotyledonous plants of moist habitats, No. 6/ *Alopecurus pratensis* dominating grass community, No. 7/ *Alopecurus pratensis-Festuca rubra* with a large share of dicotyledonous plants. In the identified communities, the share of grasses in the botanical composition ranged from 2 to 69%, other monocotyledons, including sedges, from 4 to 69%, legumes from 0 to 19% and other dicotyledonous meadow plants from 15 to 32%.

Based on the monitoring of the pasture during vegetation periods within investigation years the biomass yield available for cattle ranged from 0.8 to 2.7 t DM per ha, depending on grass community (Fig. 1).

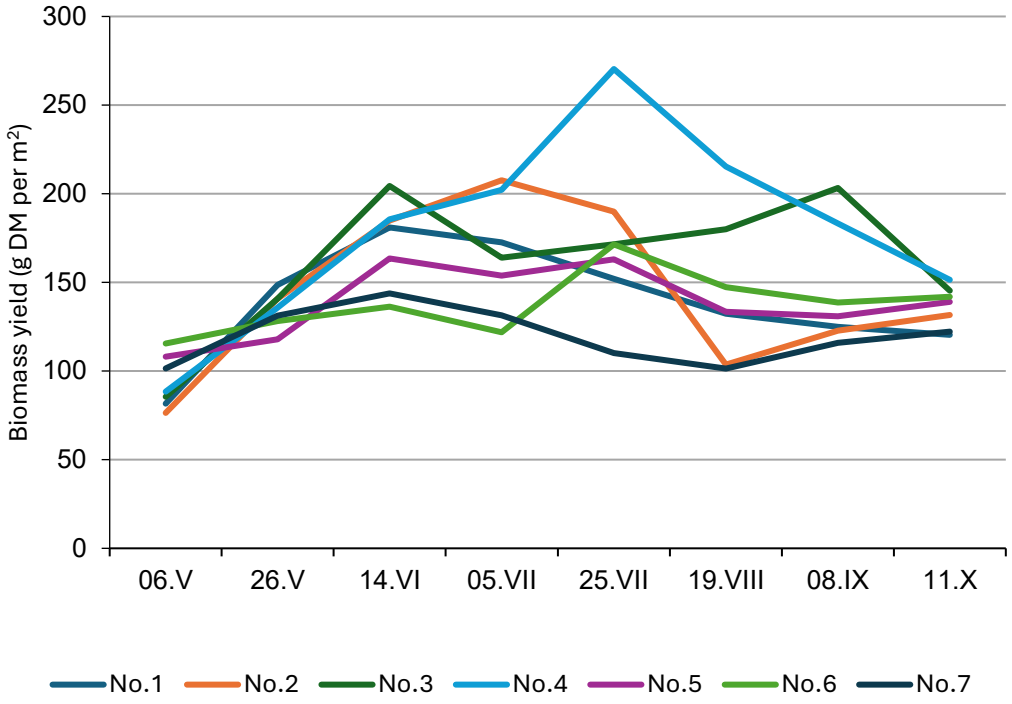

Figure 1. Changes in biomass yield available for grazing of suckler cows during vegetation period (explanation of the No. 1-7 communities given in the main text)

The community of *Carex gracilis* (No. 4) was the least attractive to grazing cows. From the beginning of the vegetation period to the end of July, the sward of this community was grazed very rarely, which caused the biomass yield to increase. In the second part of the vegetation period, suckler cows also grazed the sward available from this community. A similar trend was observed in the *Alopecurus pratensis-Carex sp*. Community (No. 3). The lowest yields throughout the vegetation period were found in the *Alopecurus pratensis-Festuca rubra* community (No. 7), because it was the most attractive to grazing animals.

The chemical composition of the pasture sward varied depending on the community (Table 1). The best quality, especially in terms of higher concentration of crude protein, crude fat, β-carotene, and lower ADF, was noted in the *Poa pratensis- Festuca rubra* community (No. 1). Low quality was found in the communities No. 3 and No. 4 with a large share of hygrophilous species, particularly of the genus *Carex*.

Table 1. Chemical composition of the sward communities occurring in the pasture (average values)

Plant community*	Ash g/kg DM	Crude protein g/kg DM	Crude fat g/kg DM	Crude fibre g/kg DM	NDF g/kg DM	ADF g/kg DM	β-carotene mg/kg
1	47.4	122.6	16.5	224.0	548.9	289.0	676.9
2	43.4	114.6	12.4	219.5	526.2	289.5	533.7
3	43.5	109.0	13.7	228.6	559.2	295.8	419.9
4	43.8	110.7	10.7	225.4	571.3	292.8	522.0
5	53.9	113.0	13.9	225.8	554.1	291.9	583.0
6	57.9	102.5	14.8	225.3	515.9	297.5	554.9
7	50.9	107.8	15.2	227.5	561.6	295.1	519.1

*explanation of the 1-7 communities given in the main text

Virtual fencing to support grazing of suckler cows

Recognition of the forage potential of the pasture was the basis for preparation of the map with logical connections into IoT system. In this stage, a virtual pasture in the IoT system on a satellite map was marked up, maintaining its extensive character, as well as developing a grazing schedule, taking into account the parts dedicated to suckler cows and calves, which is the basis for the innovation of the technology. The developed grazing schedule in the river valley complex also included valuable natural and wetland enclaves, to which access of grazing animals will be periodically excluded. The virtual fence was implemented using the same principle as in commercially available systems, where a GPS collar constantly tracks the animal's position and compares it with virtual boundaries set by the farmer and collected from the collar. If the animal approaches the virtual border, the collar will produce an audio signal whose intensity and tone scale increase when the animal comes closer to the border. If the animal does not respond to the audio signal, it will receive an electric pulse. The pulse has about 30 to 50 times less energy compared to a traditional electric fence, but still, it is enough for the animals to be considered unpleasant. The cycle of the audio signal followed by the electric shock is repeated one to two more times if the animal does not respond, the animal is indicated as 'escaped'. The scheme used in our system is presented in the Figure 2. A key element of virtual fencing technology are collars equipped with built-in solar panels that charge the batteries during the day.

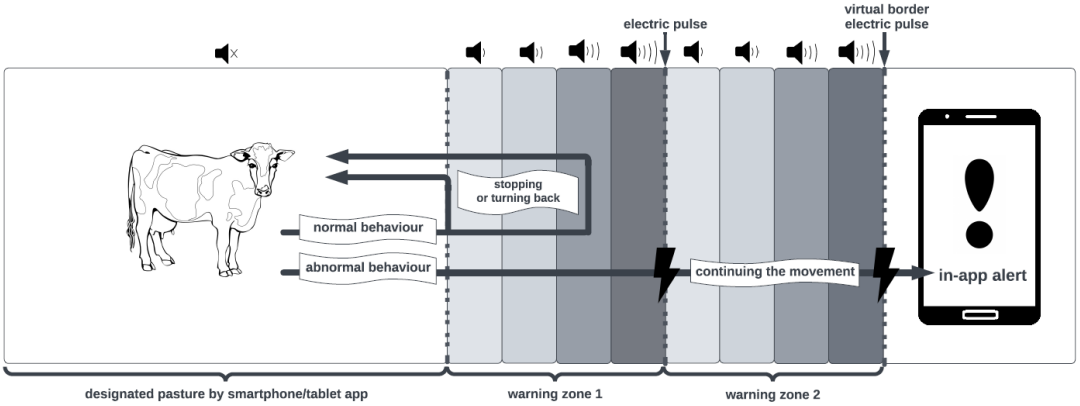

Figure 2. Scheme of possible response of grazing animals to virtual fencing in the IoT system

The next steps for developing of the technology were: field tuning of IoT system components, work on creating a virtual knowledge base, preparation of camera stations, setting camera parameters and including them in the IoT system and programming work. In 2024 the adaptation of grazing animals is in progress and the results are promising. Parallel, the zootechnical studies are conducted, which include physical monitoring of the herd, studies of the nutritional activity of suckler cows and calves in virtual quarters, ethological studies of animals, body temperature tests to detect animal diseases. Every two months from the beginning of grazing the assessment of animal weight gains during the grazing season are conducted. The IoT system supporting the technology of grazing suckler cows in high nature value areas by virtual fencing will be complemented by the analysis of the meat quality of weaned calves after slaughter. Special attention is given in preparation of the physical location and configuration of the energy storage and photovoltaic installation.

Discussion

Grass communities located in the river valleys are of both socio-economic importance (production of animal feed and products, most important elements of the natural landscape), as well as ecological importance, because as habitats for a huge number of plant and animal species, they constitute one of the most important reservoirs of biodiversity in Poland. The results of our study focusing on determination of forage potential of the studied pasture in the Middle Odra Valley confirmed that high nature value areas can be used for cattle grazing. The technology of suckler cows is particularly suited for this purpose. The premise for maintaining the high natural values of those

meadow complexes is their utilization. It was confirmed by many authors, e.g. Horn and Isselstein (2022). The using of the IoT system based on virtual fencing support grazing of suckler cows in high nature value areas, where it is often impossible to build conventional fences and constantly monitor the daily activity of animals. Furthermore, remote control of the cattle herd using collar-mounted devices will also make it possible to exclude areas with protected plant or animal species from grazing without building physical barriers. The benefits of directing grazing animals to appropriate landscape niches were also highlighted by Campbell et al. (2020) and Stevens et al. (2021) to virtually exclude from grazing landscape elements of high natural value or habitats of rare and protected species, in particular areas excluded from use in a given year in accordance with the conducted agri-environmental programs. The potential for environmental protection in the aspect of implementing the tested IoT system on similar meadow objects, due to their large area in our country, is therefore very large.

Acknowledgements

This study was supported by grant no. 00040.DDD.6509.00075.2019.04 financed by the Rural Development Program for 2014-2020 entitled "Sourcing top-quality culinary beef based on pasture feeding of cattle controlled by IoT system", acronym: ProEcoFarm.

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