Smart technologies for detecting animal welfare status and delivering health remedies for rangeland systems

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Summary

Although the emerging field of precision livestock farming (PLF) is predominantly associated with intensive animal production, there is increasing interest in applying smart technologies in extensive rangeland systems. Precision livestock farming technologies bring the possibility of closely monitoring the behaviour, liveweight and other parameters of individual animals in free-ranging systems. 'Virtual fencing', ideally based on positive reinforcement, i.e. rewarding animals for moving in a specified direction, has the potential to gently guide foraging livestock towards areas of vegetation identified by remote sensing. As well as reducing hunger, this could be integrated with weather forecasting to help ensure that animals are automatically directed to areas with appropriate shelter when adverse weather is forecast. The system could also direct animals towards handling facilities when required, reducing the fear and distress associated with being mustered. The integration of the various data collected by such a 'virtual shepherd' system should be able to rapidly detect disease and injury, and sick animals could then be automatically shepherded to an enclosure for treatment. In general, rangeland livestock already have the freedom to express normal behaviour, but PLF technologies could facilitate this. By bringing levels of monitoring and control normally associated with intensive production to rangeland systems, PLF has the potential, with appropriate adoption, to enhance the capacity of rangeland livestock production systems to meet key areas of welfare concern highlighted by the Five Freedoms.

Keywords

Cattle – Goats – Precision livestock farming – Rangeland – Sheep – Virtual fence – Virtual shepherd – Welfare.

Introduction

The development of technologies in the field of precision livestock farming (PLF) has, to date, been largely focused towards intensive animal production (1). However, there is no fundamental reason why precision technologies should not be used in rangeland systems. Many rangelands are characterised as marginal environments in the world's arid and semi-arid regions (2). They are large, open areas with predominantly natural vegetation that is grazed (and browsed) by ruminant livestock (3). In traditional systems, still operating in some countries, the animals are typically supervised during the day by a human herder and then enclosed at night for protection from predators. Rising labour costs and reduced predation risks in some parts of the world now mean that the animals in some rangeland systems have little or no human supervision or intervention for large parts of the year (3). This paper briefly reviews some of the current and emerging PLF technologies that may be of use in rangeland systems and then considers some ways in which these remote monitoring technologies might be applied in the future to the detection and treatment of animal health and welfare problems.

Current rangeland precision farming technologies

Most existing precision farming technologies that are currently being utilised in rangeland management are used to monitor vegetation growth and herbage availability (4). For example, remote sensing from satellites (e.g. the 'Pastures from Space' programme developed by the Commonwealth Scientific and Industrial Research Organisation and Western Australia's Department of Agriculture and DEpartment of Land Information) provides rangeland farmers with a tool to estimate herbage availability (5). To date, the only major PLF technology to have an impact on extensive ruminant production is electronic identification (EID) (6). This typically consists of a cheap passive transponder that is small enough to be encapsulated in an ear tag. The device transmits a unique identifier when energised by a reader, allowing the rapid identification of individual animals. Although EID tags are currently used to facilitate the identification of animals and to provide traceability (7), there is scope for using EID as part of future management systems, as discussed in the next section.

Future rangeland precision livestock farming technologies

As well as the remote sensing of herbage availability mentioned above, there are two further key PLF technologies required for managing animals on rangeland: 'virtual fencing' and the automatic recording of grazing behaviour (1).

Rising labour costs mean that livestock in many rangeland systems no longer receive daily supervision by a human herder (3). Instead, these systems rely on static fencing to rather crudely control where animals graze (8). Although the development of temporary electric fencing in the 1940s made it easier to adjust paddock boundaries, the approach is still labour intensive. 'Virtual fencing' overcomes this constraint by fitting a device to each grazing animal in order to control where it grazes (8).

Virtual fencing

The majority of the research into virtual fences has used punishment to train animals to avoid crossing a virtual fence line. In its simplest form, this consists of a signal cable laid on the ground, which is detected by electronics on a collar as the animal approaches the cable (9). This initially results in a warning sound, but if the animal continues to approach the cable it receives an electric shock similar to that delivered by an electric fence. The animal can avoid the electric shock by turning away from the signal cable when it hears the warning sound. Such a system is already commercially available (BoviGuard, Agrifence, Gloucester, United Kingdom [UK]), and scientific trials have shown it to be effective (10). A more dynamic approach to virtual fencing replaces the physical signal cable with a virtual boundary defined as a series of latitude/longitude coordinates. A Global Navigation Satellite System receiver can be used to establish an animal's position (11) and so determine if it is close to the boundary, with a warning signal followed by an electric shock if the animal attempts to cross the boundary. This approach has the advantage of allowing the virtual fences to be dynamic and easily moved, simply by sending a new set of boundary coordinates to the collar (12).

One potential problem with the virtual fence systems described so far is their reliance on a 'shock collar' mounted on the animal. There is already public opposition to such devices on welfare grounds in some countries, and whilst alternative aversive stimuli (e.g. unpleasant noises) have been explored, these were not as effective (13). A different, more welfare-friendly, approach is to use positive reinforcement to guide animals towards a reward (8). Such a system could use separate acoustic signals, one for each ear, to help indicate to the animal the direction of the reinforcement. This may be some concentrate feed, perhaps delivered by a robot, or receiving fresh pasture may be enough of a reward in itself. In the case of fresh herbage as a reward, there may be a need for a physical boundary, ideally with a remote-opening gate, to prevent animals gaining access to the area ahead of schedule.

Recording grazing and other animal parameters

A variety of sensors such as tilt switches and accelerometers can be used to determine, with varying degrees of success, when an animal is grazing (see 14 for a review). A bioacoustics approach shows the greatest potential (15), as it can be used to automatically detect bites and chews (16) as well as to estimate herbage intake (17). The commercial potential of bioacoustics has already been demonstrated in a rumination monitor for use with dairy cows (18). It should also be possible to use other sensors to record other aspects of animal behaviour. For example, tilt switches can record lying, standing and walking behaviour (19), and EID readers could be located at water points to record when animals drink. An important measure of animal production is liveweight, and automatic 'walk-over-weigh' systems are under development (20). These consist of electronic scales connected to an EID reader, allowing the weight of any animal that passes the device to be recorded. These can be placed at access points to strategic resources such as water so that animals will pass over them and be weighed at regular intervals.

The virtual shepherd

A system that integrates virtual fencing, grazing and other behaviour recording, liveweight monitoring and other external inputs, such as weather forecasting, could provide an automatic, dynamic approach to rangeland animal husbandry. Conceived as a 'virtual shepherd', this would, to some extent, replicate the close supervision afforded by a human herder in more traditional systems. Such a system could have a positive impact on rangeland animal welfare, as discussed in the next section.

Potential impact of precision livestock farming on extensively reared ruminant livestock

The UK Farm Animal Welfare Council's Five Freedoms and the associated recommended actions (21, 22) provide a useful framework for managing animal welfare, with potential for application to rangeland PLF, as discussed below.

Freedom from hunger and thirst – by ready access to fresh water and a diet to maintain full health and vigour

Rangeland animals achieve most of their nutrition through grazing, and this can be of variable quantity and/or quality (3). Technologies that allow grazing behaviour and intake to be monitored and controlled when integrated into a virtual shepherd system could help to reduce the risk of animals going hungry, by guiding them towards areas of fresh herbage identified by remote sensing. The system could also indicate when there is insufficient herbage to graze and that supplementary feed is needed. Rangeland animals often have to rely on natural sources of water, including streams and rivers. There are times of the year when water, sources may be unreliable, for example, when frozen in winter or dried up during a summer drought (3). A combination of sensors fitted at watering points and weather forecasting could be used to warn farmers when water supplies are likely to freeze or dry up so that appropriate action can be taken.

Freedom from pain, injury or disease – by prevention or rapid diagnosis and treatment

Unlike their intensively reared counterparts, animals in extensive rangeland systems are not usually inspected regularly, so injury and disease can go undiagnosed for long periods of time (7). Pain, injury and disease result in changes in behaviour, some of which may be quite subtle (23). Automatic monitoring of the behaviour of individual animals, including movement, grazing and lying, as well as individual liveweights, should allow rapid detection of deviations from normal values, thereby offering the potential for early warning of health problems that affect these parameters. The virtual shepherd could then guide a sick or injured animal that is still mobile, along with a few of its usual flock or herd mates for company, to a handling area for inspection by the farmer or a veterinarian.

In some parts of the world predation is a significant cause of livestock injury and death. The virtual shepherd could guide animals to areas less prone to predation at times of greatest risk, for example, around parturition. Alternatively, technology could be used to deter the predators themselves from attacking domestic stock (24).

Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area

Livestock in rangeland systems are exposed to the weather (22). Although the animals will naturally try to seek shelter when required, the virtual shepherd could use weather forecasts to guide animals towards more appropriate areas ahead of extreme weather. For example, the virtual shepherd could guide animals to shaded areas of pasture when sunny weather is forecast, and then to less shaded areas in cloudy conditions.

Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering

By helping to ensure that animals have adequate food, water and shelter, PLF technologies should reduce the distress associated with the inadequate provision of these resources (23). One of the main sources of fear in extensively managed animals is that associated with being mustered, gathered or rounded up (3). This uses the animals' natural fear responses by exposing them to predator-like or other challenging stimuli. These may include the following: dogs; humans on horseback, motor cycles or farm bikes; and humans in other land vehicles or helicopters. The virtual shepherd could reduce this fear by gently guiding animals towards handling facilities.

Freedom to express normal behaviour – by providing sufficient space, proper facilities and company of the animals' own kind

One of the main animal welfare benefits of extensive, compared to intensive, systems is that they generally provide animals with a greater opportunity to perform normal behaviours (23), and this would continue to be the case with rangeland management that incorporates PLF technologies.

Potential risks to animal welfare from precision livestock farming

Although PLF has the potential to significantly improve the welfare of livestock in rangeland systems, there are also some risks (25). There will be times when the technology will fail, at which point traditional husbandry will be required to meet the animals' needs. The systems also need to be fail-safe, i.e. they need to fail in a way that does not compromise animal welfare. Another risk is that farmers may be tempted to use quicker-growing but less hardy breeds in rangeland systems if they believe they could rely on the technology to help maintain intakes and detect health issues. A key message to convey to farmers is that these novel PLF technologies are intended to facilitate but not replace good stockmanship, and whether or not these new technologies are adopted and applied appropriately will require monitoring (25).

Although much of the technology required to deliver a rangeland PLF system has already been proven in principle, the main factor currently limiting adoption is cost (26). Initially, some of the benefits of PLF could be delivered even if only a few animals in each herd or flock carried the technology, although the main benefits come when it is fitted to all the animals. In one study, EIDs were shown to save so much time and labour that the technology paid for itself in one year (27), demonstrating that some aspects of PLF are already commercially viable on rangeland systems.

Conclusions

The recommended actions aligned with each of the Five Freedoms provide guidance on the potential for PLF to be deployed in ways that enhance rangeland management of animal welfare. Whilst intensive systems usually ensure adequate feed and water as well as the rapid diagnosis and treatment of injury and disease, they often restrict the expression of normal behaviour (22, 23). The PLF approach has the potential to bring the benefits of monitoring and control of nutrition and health normally associated with intensive systems to rangeland systems without compromising an animal's expression of most normal behaviour. Consequently, PLF has the potential to deliver considerable improvements in the health and welfare of domestic animals in rangeland systems by facilitating the remote and/or automatic implementation of many of the recommended actions associated with the Five Freedoms.

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Le recours aux technologies intelligentes pour la mesure du bien-être animal et la fourniture de soins dans les systèmes d'élevage au pâturage

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Résumé

L'élevage de précision est un secteur en plein essor dont les applications ont jusqu'à présent privilégié les systèmes intensifs de production animale ; néanmoins, l'utilisation de ces technologies intelligentes dans les systèmes extensifs d'élevage au pâturage suscite un intérêt croissant. Les technologies de l'élevage de précision offrent des outils permettant de contrôler de près le comportement, le poids vif et d'autres paramètres de l'animal élevé au pâturage. Les « clôtures virtuelles », qui reposent idéalement sur l'utilisation d'attracteurs positifs, c'est-à-dire l'attribution d'une récompense lorsque les animaux se déplacent dans la direction voulue, présentent l'avantage supplémentaire d'orienter avec douceur les animaux vers des zones de fourrage vert préalablement identifiées par des capteurs. En plus de limiter la faim dans les troupeaux, cette méthode, associée à la prise en compte des prévisions météorologiques, pourrait permettre de diriger automatiquement les animaux vers des zones où ils peuvent s'abriter en cas d'intempéries. Ce système peut également orienter les animaux vers les bâtiments d'élevage aux moments souhaités, minimisant ainsi la peur et la détresse associées aux rassemblements de bétail. Ce « berger électronique » peut recueillir des données extrêmement diverses et devrait ainsi permettre de détecter rapidement les animaux malades ou blessés, pour les diriger ensuite automatiquement vers un enclos où ils seront soignés. En général, les animaux élevés au pâturage sont libres d'exprimer leur comportement normal, liberté que les technologies de l'élevage de précision pourraient favoriser encore plus. En mettant à la portée des systèmes d'élevage au pâturage des niveaux de suivi et de contrôle généralement associés à la production intensive, l'élevage de précision, s'il est appliqué de manière appropriée, pourrait améliorer les capacités des systèmes de protection extensifs à respecter les aspects cruciaux du bien-être animal tels que les traduit le concept des « cinq besoins fondamentaux ».

Mots-clés
Berger virtuel – Bien-être animal – Bovins – Caprins – Clôture virtuelle – Élevage au pâturage – Élevage de précision – Ovins.

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Tecnología inteligente para determinar el estado de bienestar animal y administrar remedios sanitarios en sistemas de pasto

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Resumen
Aunque el novedoso ámbito de trabajo de la ganadería de precisión (*precision livestock farming*) viene ligado sobre todo a la producción animal intensiva, existe un creciente interés por la aplicación de tecnología inteligente a sistemas de pasto extensivos. Las técnicas de la ganadería de precisión ofrecen la posibilidad de seguir muy de cerca el comportamiento, el peso vivo y otros parámetros individuales de los animales que pastan al aire libre. La creación de «vallas virtuales», basada en la idea del refuerzo positivo, esto es, el hecho de recompensar a los animales por moverse en determinada dirección, ofrece la posibilidad de orientar suavemente al ganado para que en su búsqueda de buenos pastos se dirija a determinadas zonas de vegetación localizadas por teledetección. Ello no solo reduce el hambre, sino que además se puede integrar con las previsiones meteorológicas para ayudar a dirigir automáticamente a los animales hacia zonas provistas de cobijo adecuado cuando se prevea mal tiempo. El sistema también podría servir para dirigir al ganado hacia las instalaciones de manipulación cuando fuera necesario, reduciendo el nivel de miedo y ansiedad que generan en los animales las operaciones de reagrupamiento. La integración de los diversos datos recogidos gracias a semejante sistema de «pastoreo virtual» debería ayudar a detectar rápidamente enfermedades y lesiones, y en tal caso dirigir automáticamente hacia un establo a los animales afectados para dispensarles tratamiento. En general, los vacunos de pasto ya gozan de la libertad de conducirse con naturalidad, pero la tecnología de la ganadería de precisión

podría abundar aún más en este sentido. Al aportar a los sistemas de pasto los niveles de seguimiento y control normalmente asociados a la producción intensiva, la ganadería de precisión, adecuadamente aplicada, abre las puertas para que los sistemas de pasto puedan cumplir en mayor medida los requisitos básicos de bienestar concretados en lo que ha dado en llamarse las «cinco libertades».

Palabras clave
Bienestar – Cabras – Ganadería de precisión – Ganado vacuno – Ovejas – Pasto – Pastoreo virtual – Valla virtual.

References

1. Rutter S.M. (2012). – A 'smart' future for ruminant livestock production. *Cattle Pract.*, **20** (3), 186–193.

2. Ash A.J. & McIvor J.G. (2005). – Constraints to pastoral systems in marginal environments. *In* Pastoral systems in marginal environments (J.A. Milne, ed.). Wageningen Academic Press, Wageningen, the Netherlands, 17–28.

3. Phillips C.J.C. (2010). – Principles of cattle production. CABI, Wallingford, United Kingdom.

4. Schellberg J., Hill M.J., Gerhards R., Rothmund M. & Braun M. (2008). – Precision agriculture on grassland: applications, perspectives and constraints. *Eur. J. Agron.*, **29**, 59–71.

5. Hill M.J., Donald G.E., Hyder M.W. & Smith R.C.G. (2004). – Estimation of pasture growth rate in the south west of Western Australia from AVHRR NDVI and climate data. *Remote Sensing Environ.*, **93**, 528–545.

6. Artmann R. (1999). – Electronic identification systems: state of the art and their further development. *Comput. Electron. Agric.*, **24**, 5–26.

7. Goddard P.J. (2008). – The management of sheep. *In* The welfare of sheep (C. Dwyer, ed.). Springer, Dordrecht, the Netherlands, 291–323.

8. Umstatter C. (2011). – The evolution of electric fences: a review. *Comput. Electron. Agric.*, **75**, 10–22.

9. Monod M.O., Faure P., Moiroux L. & Rameau P. (2009). – Stakeless fencing for mountain pastures. *In* Precision livestock farming '09 (C. Lockhorst & P.W.G. Groot Koerkamp, eds). Wageningen Academic Press, Wageningen, the Netherlands, 175–181.

10. Umstatter C., Morgan-Davies J. & Haskell M. (2012). – Study of cattle responses to an 'invisible fence' approach. *In* Proc. Australian and New Zealand Spatially Enabled Livestock Management Symposium, 6 July, Lincoln, New Zealand. Available at: www.agresearch.co.nz/our-science/land-environment/soils-land-use/docs/SELM%20Abstracts%202012%20(4MB).pdf (accessed on 19 February 2013).

11. Rutter S.M., Beresford N.A. & Roberts G. (1997). – Use of GPS to identify the grazing areas of hill sheep. *Comput. Electron. Agric.*, **17**, 177–188.

12. Anderson D.M. (2006). – Virtual fencing: a concept into reality. *In* Proc. Spatial grazing behaviour workshop. Commonwealth Scientific and Industrial Research Organisation, Rockhampton, Queensland, 61–91.

13. Umstatter C., Tailleur C., Ross D. & Haskell M.J. (2009). – Could virtual fences work without giving cows electric shocks? *In* Precision livestock farming '09 (C. Lockhorst & P.W.G. Groot Koerkamp, eds). Wageningen Academic Press, Wageningen, the Netherlands, 161–168.

14. Rutter S.M., Champion R.A. & Penning P.D. (1997). – An automatic system to record foraging behaviour in free-ranging ruminants. *Appl. anim. Behav. Sci.*, **54**, 185–195.

15. Ungar E.D. & Rutter S.M. (2006). – Classifying cattle jaw movements: comparing IGER Behaviour Recorder and acoustic techniques. *Appl. anim. Behav. Sci.*, **98**, 11–27.

16. Milone D.H., Galli J.R., Cangiano C.A., Rufiner H.L. & Laca E.A. (2012). – Automatic recognition of ingestive sounds of cattle based on hidden Markov models. *Comput. Electron. Agric.*, **87**, 51–55.

17. Laca E.A. & WallisDeVries M.F. (2000). – Acoustic measurement of intake and grazing behaviour of cattle. *Grass For. Sci.*, **55**, 97–104.

18. Elischer M.F., Arceo M.E., Karcher E.L. & Siegford J.M. (2013). – Validating the accuracy of activity and rumination monitor data from dairy cows housed in a pasture-based automatic milking system. *J. Dairy Sci.*, **96**, 6412–6422.

19. Champion R.A., Rutter S.M. & Penning P.D. (1997). – An automatic system to monitor lying, standing and walking behaviour of grazing animals. *Appl. anim. Behav. Sci.*, **54**, 291–305.

20. Charmley E., Gowan T. & Duynisveld J. (2006). – Development of a remote method for the recording of cattle weights under field conditions. *Aust. J. experim. Agric.*, **46**, 831–836.

21. Farm Animal Welfare Council (1979). – Press release, 5 December. Available at: www.fawc.org.uk/pdf/fivefreedoms1979.pdf (accessed on 31 July 2012).

22. Webster J. (2005). – Animal welfare: limping towards Eden. Blackwell Publishing, Oxford.

23. Broom D.M. & Fraser A.F. (2007). – Domestic animal behaviour and welfare. CABI, Wallingford, United Kingdom.

24. Andelt W.F., Phillips R.L., Gruver K.S. & Guthrie J.W. (1999). – Coyote predation on domestic sheep deterred with electronic dog-training collar. *Wildl. Soc. Bull.*, **27**, 12–18.

25. Lawrence A.B. & Conington J. (2008). – Sheep welfare: a future perspective. *In* The welfare of sheep (C. Dwyer, ed.). Springer, Dordrecht, the Netherlands, 343–360.

26. Osborne L. (2012). – Toward a commercial virtual fencing device. *In* Proc. Australian and New Zealand Spatially Enabled Livestock Management Symposium, 6 July, Lincoln, New Zealand. Available at: www.agresearch.co.nz/our-science/land-environment/soils-land-use/docs/SELM%20Abstracts%202012%20(4MB).pdf (accessed on 19 February 2013).

27. Murray B.B., Rumbles I. & Rodenburg J. (2008). – Application of RFID technology in herd management on dairy herds in Canada. *In* Precision livestock farming '09 (C. Lockhorst & P.W.G. Groot Koerkamp, eds). Wageningen Academic Press, Wageningen, the Netherlands, 259–265.