An R Package to Compute the Energy Balance for Ruminants under Both Grazing and Pen-Fed Conditions

Taro Takahashi
University of Tokyo, Japan

Karl Behrendt
Charles Sturt University, Australia

David R. Kemp
Charles Sturt University, Australia

The XXIII International Grassland Congress (Sustainable use of Grassland Resources for Forage Production, Biodiversity and Environmental Protection) took place in New Delhi, India from November 20 through November 24, 2015.

Proceedings Editors: M. M. Roy, D. R. Malaviya, V. K. Yadav, Tejveer Singh, R. P. Sah, D. Vijay, and A. Radhakrishna

Published by Range Management Society of India

PaperID:561
Theme 2. Grassland production and utilization
Sub-theme 2.1. Quality, production, conservation and utilization

An R package to compute the energy balance for ruminants under both grazing and pen-fed conditions

Taro Takahashi[1]*, Karl Behrendt[2], David Kemp[2]
[1]The University of Tokyo, Tokyo, Japan
[2]Charles Sturt University, Orange, Australia
*Corresponding author e-mail: ataro@mail.ecc.u-tokyo.ac.jp

Keywords: Energy balance, Livestock model, Whole farm management, Winter grazing

Introduction

Grassland degradation is a serious environmental problem around the world, with off-site impacts of soil erosion affecting wider communities beyond those engaging in livestock farming (Kemp and Michalk, 2007). In order to operationalise an alternative farming system that is beneficial to both producers and the ecological environment, the energy and nutritional demands for animal production must be met, either through grassland production, supplementary feeding or the combination of the two, in an efficient manner (Kemp *et al*., 2013). The use of specialized biophysical models to estimate the energy balance of livestock is a well-proven solution to find such an economically efficient yet environmentally friendly production system. However, the initial cost borne by the user is known to be high, in terms of the financial outlay as well as the learning time.

The objective of the present paper is to introduce a newly developed tool to compute the energy balance of ruminants under both grazing and pen-fed conditions. The proposed tool takes the form of a publicly available package to be loaded onto the R platform (R Core Team, 2015). Because this platform is open-source, there is no acquisition cost associated to the introduction of the package. In addition, the high penetration rate of the platform, especially in developing regions that are amongst the most susceptible to grassland degradation, makes the learning cost of the package significantly lower than that of typical specialized software.

Materials and Methods

The *StageONE* livestock model (Takahashi *et al*., 2011) was modified and recompiled so that the program codes met the structural requirements for R packages. A steady-state model designed to run with a minimal set of data, *StageONE* combines a pasture module and an animal module within a single computational framework and predicts the energy balance of ruminants as a function of the grassland condition and the animal's own physical condition. By default, the results are reported monthly, in the unit of metabolisable energy per day (MJ/day) for average adult females. The central function of the package, stageone, is called with the following command:

Stageone (species = "sheep", pasture, grazing = rep(1, 12), supplement, climate, sr = 1.0, swr = 45.0, lambing = 1, weaning = 5, sales = 9, years = 6) where the entries after the equal signs are the default values. The arguments are:

species	a string specifying the type of livestock (sheep, goat, cattle or yak)
pasture	a 4 × 12 matrix specifying the standard pasture growth rate (kg DM/day) and the digestibility (%) for two different pools of grasses (desirable species and undesirable species) at each month
grazing	a 1 × 12 matrix (or a vector) specifying whether the animals are grazing (= 1) or pen-fed (= 0) at each month
supplement	a 2 × 12 matrix specifying the amount of supplements fed (kg DM/day) and their overall digestibility (%) at each month
climate	a 3 × 12 matrix specifying the average temperature (°C), the average precipitation (mm/day) and the average wind velocity (km/h) at each month
sr	a numeric specifying the stoking rate, hereby defined as the number of adult females per hectare
swr	a numeric specifying the standard reference weight of an average adult female

lambing	an integer specifying the Julian month (1 for January, 2 for February…) for lambing
weaning	an integer specifying the Julian month (1 for January, 2 for February…) for weaning
sales	an integer specifying the Julian month (1 for January, 2 for February…) for lamb sales
years	an integer specifying the number of times an average female gives births and lactates before being replaced by maidens

Based on these inputs, the function returns a 2 × 12 matrix that summarizes the energy intake (MJ/day) and the energy requirement for typical adult females at each month, with the difference between the two values representing the energy balance that corresponds to the animal's bodyweight change. For a visual assessment, a graphics window depicting these two curves is also produced.

Results and Discussion

As an application of the stageone function, a sheep experiment reported by Zheng *et al*. (2013) was replicated using the proposed package. The original experiment was carried out in Taipusi County (41°35′–42°10′N, 114°51′–115°49′E) of China's Inner Mongolia Autonomous Region, where traditional winter grazing on pastures with virtually no herbage mass had been thought to be exacerbating the grassland condition and counterproductive to animal production. To demonstrate that the energy gained from this practice was less than that lost to the cold and exercise requirements, 40 Mongolian Mutton Cross ewes (Group A) were kept inside greenhouse sheds throughout the winter of 2008/09 (November to May), while another 40 ewes of the same breed (Group B) were left grazing in the traditional method. Group A ewes were not let out of the sheds except for 2 hours per day set aside for water and exercises, whereas Group B ewes were grazing daily on the village's communal grassland between 8am and 5pm and put back to the conventional brick-roofed sheds at the fall of the evening. Both groups were fed with the same ration of supplements as per their traditional farming strategy: hay, maize silage and maize grain three times per day. The experiment showed a statistically significant difference in the winter bodyweight loss suffered by the two groups, with Group A ewes weighing 3.3 kg heavier on average than Group B ewes at the end of the season.

Fig. 1 is the graphical output from the proposed package for the two groups of animals. The figure shows that while the actual intake of the metabolisable energy is almost identical across the groups, the maintenance requirement is significantly higher for Group B—by around 3.0 MJ per day at the height of winter. These two facts suggest that winter grazing offers very little amount of feed (of very low digestibility) to animals while the cold environment and the extra walking distance take a large amount of additional energy off their bodies. This, in turn, leads Groups B animals to a larger energy deficit, a finding consistent with the aforementioned observed weight changes. Zheng *et al*. (2013) estimate that the economic benefit of the greenhouse shed (gross of the cost of the shed) is around CNY 60, or USD 9, per adult ewe per year.

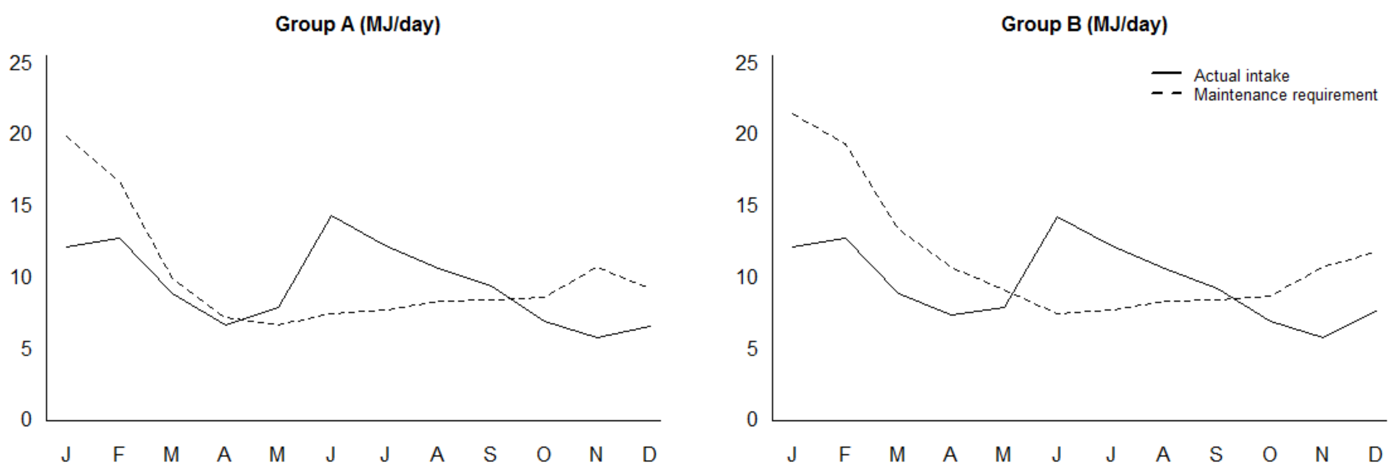

Fig 1. Graphical outputs for Group A ewes (left) and Group B ewes (right)

Conclusion

The above example demonstrates that an open-source tool to estimate the energy balance of livestock has a potential to help design an improved farming system in regions where the present system is found to be unsustainable. Visualization of the energy balance can be a useful communication method with farmers and extension officers, especially when the newly suggested strategy is counterintuitive to them. Additional functionality for the package to automatically find the optimal stocking rate is currently under development.

References

Kemp, D. R., G. Han, X. Hou, D. L. Michalk, F. Hou, J. Wu and Y. Zhang. 2013. Innovative grassland management systems for environmental and livelihood benefits. *Proc. Natl. Acad. Sci.* 110: 8369-8374.

Kemp, D.R. and D. L. Michalk. 2007. Towards sustainable grassland and livestock management. *J. Agric. Sci.* 145: 543-564.

R Core Team. 2015. *R: A language and environment for statistical computing*. Vienna: R Foundation for Statistical Computing. http://www.R-project.org/.

Takahashi, T., R. E. Jones and D. R. Kemp. 2011. Steady-state modelling for better understanding of current livestock production systems and for exploring optimal short-term strategies. In: D.R. Kemp and D.L. Michalk (eds) *Development of Sustainable Livestock Systems on Grasslands in North-western China*. Canberra: Australian Centre for International Agricultural Research, 26-35.

Zheng, Y., T. Takahashi and D. R. Kemp. 2013. Energy and economic values of greenhouse sheds to replace winter grazing in northwestern China. *Grassl. Sci.* 59: 156-159.

Acknowledgement

This research was funded by Australian Centre for International Agricultural Research (LPS/2008/048).