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LETTER TO THE EDITOR

WILEY Global Change Biology

A narrower gap of grazing intensity. Reply to Fetzel et al., 2017. Seasonality constrains to livestock grazing intensity

Fetzel, Havlik, Herrero, & Erb (2017) globally mapped the gap between observed and potential grazing intensity (GI): the ratio between consumption by livestock and aboveground net primary productivity (ANPP). Fetzel et al. (2017) estimated grazing land, forage production and livestock demand at a half-degree resolution. They mapped GI below 15% for most of the world. Here we present some independent tests of their predictions and show that observed GI reported in the literature is consistently higher than observed GI reported by Fetzel et al. (2017). Consequently, the gap between forage produced and consumed may be narrower.

We present seven examples that show higher GI than Fetzel et al. (2017) (Table 1). The first two examples are global (Table 1; McNaughton, Oesterheld, Frank, & Williams, 1989; Milchunas & Lauenroth, 1993; Oesterheld, Loreti, Semmartin, & Paruelo, 1999). They show that livestock GI estimated by Fetzel et al. (2017) are within the range of GI in natural systems dominated by invertebrates and well below systems dominated by vertebrate herbivores or livestock (Table 1, see Fig. 1 by Fetzel et al., 2017). The other examples are regional and focus on livestock. Two regional compilations for South American livestock production systems (Irisarri, Oesterheld, Golluscio, & Paruelo, 2014; Oesterheld et al.,1999) had higher GI values than estimated by Fetzel et al. (2017) for the same region. The remaining three examples correspond to two of the most important rangeland areas of North America, the Northern Mixed Grass Prairie and the Short Grass Steppe. There, rangeland scientists have reproduced ranchers GI levels in long-term experiments (Biondini, Patton, & Nyren, 1998; Derner & Hart, 2007; Milchunas, Forwood, & Lauenroth, 1994). In all cases, the simulated GI (-40%) was higher than the maximum values by Fetzel et al. (2017) for those vast areas. Moreover, the maximum GI value from the long-term experiments almost doubled the maximum GI by Fetzel et al. (2017). In summary, most reports of GI in the literature are above the 0-15% GI reported by Fetzel et al. (2017) for most of the world.

TABLE 1 Seven examples from eight different literature references in which grazing intensity (GI) was estimated across different levels of aboveground net primary production (ANPP). In all cases, GI was estimated as the ratio between animal consumption and ANPP

							Fetzel et al. (2017)	
Id	Site	Grazing system	Reference	ANPP range kg/ha.year	ANPP estimation method	GI range (%)	GI range real (%)	GI range potential (%)*
1	Worldwide	Natural systems dominated by vertebrates	McNaughton et al. (1989); Oesterheld et al. (1999)	1000–10000	Estimated through linear associations between MAP and ANPP	30–75 (vertebrates) 5–10 (invertebrates)	0–70	0–50
2	Worldwide	Rangeland majorly beef production	Milchunas and Lauenroth (1993)	240–4430	Diverse methods	8–85	0–70	0–50
3	Southern South America	Rangeland majorly beef production	Oesterheld et al. (1999)	500–10000	Estimated through linear associations between MAP and ANPP	5–60	0–15*[1]	0–50*[1]
4	Southern South America	Rangeland wool and beef production	Irisarri et al. (2014)	500–10000	Estimated through linear associations between MAP and ANPP	6–67	0–15*[1]	0–50*[1]
5	Northern Mixed Prairie (USA)	Rangeland beef production	Biondini et al. (1998)	2000–4000	Clipped biomass	50–90	0–15*[2]	0–5*[2]
6	Northern Mixed Prairie (USA)	Rangeland beef production	Derner & Hart (2007)	500–2350	Clipped biomass	20–60	0–15*[2]	0–5*[2]
7	Short Grass Steppe (USA)	Rangeland beef production	Milchunas et al. (1994)	200–1700	Clipped biomass	20–60	0–15*[3]	0–5*[3]

*The selected values were obtained considering the range observed within different polygons representative of the cited literature. [1]lower left: 40.31S; 71.09W lower right: 41.94S; 65.34W upper right: 33.28S; 53.03W upper left: 28.97S; 58.71W. [2]lower left: 41.04N; 105.69W lower right: 41.34N; 97.53W upper right: 48.95N; 97.87W upper left: 48.96N; 113.31W. [3]lower left: 32.85N; 105.60W lower right: 32.85N; 101.81W upper right: 40.79N; 100.81W upper left: 40.82N; 105.04W.

Why are estimates of GI in Table 1 higher than in Fetzel et al. (2017)? Estimating GI requires estimating ANPP and consumption. Regarding ANPP, the examples in Table 1 used either field data or empirical models based on precipitation (reviewed by Sala, Gherardi, Reichmann, Jobbágy, & Peters, 2012). Fetzel et al. (2017) used two global simulation models: JULES, which overestimates net primary production (NPP), particularly in the tropics (Slevin, Tett, Exbrayat, Bloom, & Williams, 2016) and ORCHIDEE, which overestimates NPP at low levels of production (Chang et al., 2015). In addition, Fetzel et al. (2017) estimated ANPP as 60% of NPP, higher than the 43% average reported for grasslands and shrublands across the world (Scurlock & Olson, 2013). Thus, overestimation of ANPP, the denominator of GI, may be one of the reasons for the different results. Estimating livestock consumption involves livestock number, individual consumption, and rangeland area. Because individual consumption is usually estimated as a percentage of live weight (2-3% of body mass), the discrepancies between Fetzel et al. (2017) and Table 1 must stem from livestock number and/or rangeland area. Regarding livestock number, example 1 used literature sources, whereas example 3 and Fetzel et al. (2017) used national statistics, which share considerable uncertainty. Examples 2, and 4 to 7 used actual numbers from trials with livestock (Biondini et al., 1998; Derner & Hart 2007; Milchunas & Lauenroth, 1993; Milchunas et al., 1994) or ranch counts (Irisarri et al., 2014), both with low uncertainty. Regarding rangeland area, example 3 used national statistics (Oesterheld et al., 1999), while Fetzel et al. (2017) used a land cover map. Both cases share some level of uncertainty associated with either the data source (example 3) or the classification error (Fetzel et al., 2017). Fetzel et al. (2017) stated that their grazed land estimate was at the upper end of other estimates because it included potential area not currently grazed. All the other examples from Table 1 used the actual grazed area which again has low uncertainty. Thus, Fetzel et al. (2017) may have overestimated rangeland area and so underestimated animal density and consumption. In summary, an underestimated consumption over an overestimated ANPP generated un underestimation of GI.

We agree with Fetzel et al. (2017) that livestock production gap is a critical area of study (Pacin & Oesterheld, 2015). However, the livestock production gap should be decomposed into a GI gap (efficiency of ANPP consumption) and a feed conversion gap (efficiency of livestock production per unit consumed). We here showed that the GI gap is narrower than proposed by Fetzel et al. (2017). In addition to working on this gap, technology and policy should consider closing the feed conversion gap (for example, by controlling mating period and thus increasing weaning rates). We also showed that we need better global estimates of forage production, livestock abundance and livestock area.

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REFERENCES

Biondini, M. E., Patton, B. D., & Nyren, P. E. (1998). Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. *Ecological Applications*, *8*, 469–479.

Chang, J., Viovy, N., Vuichard, N., Ciais, P., Campioli, M., Klumpp, K., & Soussana, J. F. (2015). Modeled changes in potential grassland productivity and in grass-fed ruminant livestock density in Europe over 1961–2010. *PLoS One*, *10*, e0127554.

Derner, J. D., & Hart, R. H. (2007). Grazing-induced modifications to peak standing crop in northern mixed-grass prairie. *Rangeland Ecology & Management*, *60*, 270–276.

Fetzel, T., Havlik, P., Herrero, M., & Erb, K. H. (2017). Seasonality constraints to livestock grazing intensity. *Global Change Biology*, *23*, 1636–1647.

Irisarri, J. G., Oesterheld, M., Golluscio, R. A., & Paruelo, J. M. (2014). Effects of animal husbandry on secondary production and trophic efficiency at a regional scale. *Ecosystems*, *17*, 738–749.

McNaughton, S. J., Oesterheld, M., Frank, D. A., & Williams, K. J. (1989). Ecosystem-level patterns of primary productivity and herbivory in terrestrial habitats. *Nature*, *341*, 142–144.

Milchunas, D. G., Forwood, J. R., & Lauenroth, W. K. (1994). Productivity of long-term grazing treatments in response to seasonal precipitation. *Journal of Range Management*, *47*, 133–139.

Milchunas, D. G., & Lauenroth, W. K. (1993). Quantitative effects of grazing on vegetation and soils over a global range of environments. *Ecological monographs*, *63*, 327–366.

Oesterheld, M., Loreti, J., Semmartin, M., & Paruelo, J. M. (1999). Grazing, fire, and climate effects on primary productivity of grasslands and savannas. In L. Walker (Ed.), *Ecosystems of disturbed ground* (pp. 287–306). Amsterdam: Elsevier.

Oesterheld, M., Sala, O. E., & McNaughton, S. J. (1992). Effect of animal husbandry on herbivore-carrying capacity at a regional scale. *Nature*, *356*, 234–236.

Pacin, F., & Oesterheld, M. (2015). Closing the technological gap of animal and crop production through technical assistance. *Agricultural Systems*, *137*, 101–107.

Sala, O. E., Gherardi, L., Reichmann, L., Jobbágy, E., & Peters, D. (2012). Legacies of precipitation fluctuations on primary production: Theory and data synthesis. *Philosophical Transactions Royal Society London B Biological Sciences*, *367*, 3135–3144.

Scurlock, J. M. O., & Olson, R. J. (2013). *NPP multi-biome: Grassland, Boreal Forest, and Tropical Forest Sites, 1939-1996, R1*. Oak Ridge, TN: ORNL DAAC.

Slevin, D., Tett, S. F., Exbrayat, J. F., Bloom, A. A., & Williams, M. (2016). Global evaluation of gross primary productivity in the jules land surface model v3. 4.1. *Geoscientific Model Development Discussions*, *10*, 2651–2670. 2016.