Towards sustainable livestock production systems: Analyzing ecological constraints to grazing intensity

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Introduction

Food production from grasslands is essential: Grasslands provide 33% of total protein and 17% of total calorie consumption (Herrero et al. 2009, 2013) and make an otherwise unusable resource available to humans. Current sustainability problems on worlds grasslands (e.g. soil erosion) caused by the conversion of natural ecosystems like forests to pasture and overgrazing pose new challenges to find sustainable ways of increasing food production. A sound understanding of the major determinants and constraints of global livestock production systems is key in this context. We explore ecological constraints to grazing intensity by:

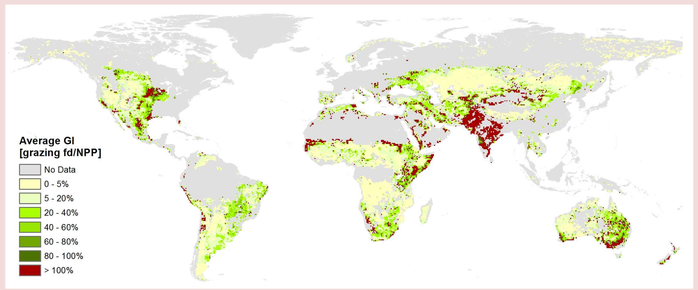
- analysing spatial patterns of grazing intensity (GI; Fig. 1)
- determining the role of seasonality using monthly NPP data and estimating the number of months in which supplementary feed is necessary
- estimating the potential accessible and utilizable NPP (NPP_{au}) and the surplus NPP available during biomass growth cycles. Social organization (e.g. storage) could help to bridge periods of deficiency.

Results

Distribution of GI in world's grazing lands (% of NPP removed):

- 84% of total area: 0-40%
- 9%: 40 –100%
- 7%: >100% (e.g. feed-demand exceeds the estimated available NPP caused by data uncertainties in estimated feed composition or NPP data)

Fig. 1: Grazing intensity (e.g. the fraction of available Net Primary Production (NPP) consumed by grazing animals in a year; GI>100% represents areas where NPP is not sufficient to cover the estimated grazers feed demand – e.g. represents data uncertainty)



World regions: CA&RUSSIA=Central Asia and Russia, E&SE EUR = Eastern and South-Eastern Europe, EA = Eastern Asia, LAM = Latin America, NAWA = Northern Africa & Western Asia, NA = North America, OCE = Oceania, SEA = South-Eastern Asia, SA = Southern Asia, SSA = Sub-Saharan-Africa, WEUR = Western Europe

Results

Fig. 2: NPP_{au} balance in gC/m²/yr; a negative balance indicates that annual NPP_{au} is not sufficient to cover the grazers feed-demand; a positive balance indicates potentially available surplus biomass;

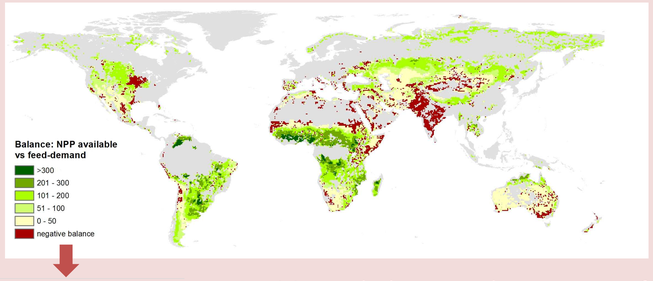


Fig. 3: Average NPP_{au} balance for world regions in gC/m²/yr

Fig. 4: Uncertainty of NPP_{au} balance based on two NPP estimates and min, mean and max utilization levels: All positive/negative = total agreement, 5 pos 1 neg = 5 out of 6 estimates are positiv.

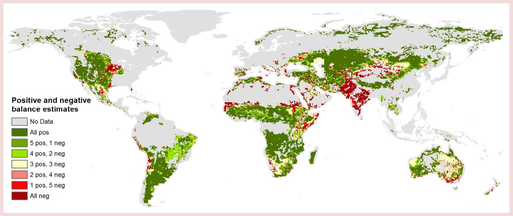
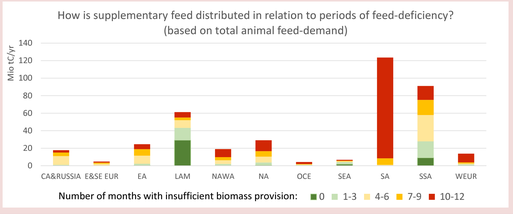


Fig. 5: Supplementary feed in tC/yr in world regions broken down to number of months that need to be bridged.



- Positive balance: hotspots of available surplus NPP_{au} in LAM and SSA, smaller potential in all regions except SA
- Negative balance: insufficient NPP_{au} provision due to very high stocking densities, uncertainties and low productivity in arid areas (NAWA&SA)
- Uncertainty: In large parts of the world all estimates agree to a positive balance (NA, LAM, CA&RUSSIA and SSA); exception: SA (Fig. 3 and 4), Sahel zone and Central NA.
- Supplementary feed is highest in SA followed by SSA
- Most supplementary feed is fed in regions where NPP_{au} supply is seasonally insufficient (e.g. 1-12 months, Fig. 5)
- LAM and SSA: Supplementary feed fed in regions where NPP_{au} supply is actually sufficient according to our balance estimate (dark green, Fig. 5)

Conclusions

- Grazing intensity (GI) is between 0 and 40% on 84%, between 40 and 100% on 9%, and exceed available NPP on the remaining 7% of world's grazing lands (Fig. 1)
- Depending on local ecological characteristics and limits to stocking density, areas with very low GI could exhibit potential to more efficiently use the available resource.
- Total supplementary feed makes **up for almost 0.4 GtC/yr**
- Our balance estimates suggest that an **NPP_{au} flow of approximately 2.3 GtC/yr** could come from utilizing (seasonally) available surplus NPP_{au} by societal organization (e.g. storage)
- More than ½ of this is located in areas with seasonally constrained NPP_{au}
- 47% of this (approx. 1 GtC/yr) is located in areas with no seasonal constraints in particular in SSA (48%) and LAM (41%), however uncertainty is very large (2.1 – 0.2 GtC/yr) and these areas often are biodiversity hotspots.

Precaution in interpretation:

- Massive logistic efforts necessary to yield this potential and trade-offs need to be considered
- **Biodiversity loss** or the maintenance of **soil fertility** need to be considered, but are not quantifiable today due to knowledge gaps
- Avoiding further **land expansion** and **soil degradation** is essential
- Understanding the systemic inter-linkages between GI, sustainable utilization levels as well as socio-economic and ecological trade-offs from the global to the local scale is essential to better understand the potentials unfolded by utilizing (seasonal) surplus NPP_{au}.

Data sources	Citation
Grazers feed demand	Herrero et al. 2013; Krausmann et al. 2013
Livestock distribution – Gridded Livestock of the World (GLW)	FAO 2007
NPP (annual and monthly); JULES and ORCHIDEE	Earth System Grid Federation 2013
Grazing area	Erb et al. 2007
Restriction of grazing area:	
Potential grazing based on: Olson, FAO Ecozones, Foley/Ramankutty potveg.	FAO 2008, Olson et al. 2001, Foley and Ramankutty 2010
IUCN protected areas	IUCN 2015
Accessibility and utilization (NPPau)	Milchunas and Lauenroth 1993; own literature survey

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