ARIES for SEEA Global runs

Grazing Biomass Provisioning

Deliverable 3: Global results

under the KM-GBF Project between UN-DESA and BC3

Author: Megan Critchley
Release date: 1 Apr 2026

Index

On computing global results for grazed biomass provisioning

Overview of grazed biomass provisioning services

Globally, livestock production is crucial to maintaining the livelihoods and food security of human populations. Demand for livestock production has been a significant driver of land conversion, degradation and deforestation. However, livestock production (and grazing) exists in many forms. Livestock production can support small-holder income and well-managed pastures and extensive livestock grazing systems can play a role in enhancing biodiversity and carbon storage outcomes (Parente *et al.* 2025). Protecting, conserving and restoring grasslands is critical to ensuring nature's ability to support this service.

Grazed biomass provisioning services are ecosystem contributions to the growth of grazed biomass that is an input to the growth of livestock (SEEA-EA Table 6.3). Grazing biomass forage is supplied from natural and semi-naural ecosystems such as grasslands, shrublands, savannas and some woodlands, as well as anthropogenic ecosystems including cultivated pastures and some croplands (e.g. mosaic systems). This module will focus on the contributions of natural/semi-natural ecosystems. The provision of this service is driven by the availability, accessibility and productivity of these ecosystems. Factors such as climate (including extreme events such as drought), ecosystem condition, elevation and accessibility all affect the level of productivity and suitability of ecosystems to support this service.

Objective of the module

This module spatially maps the biophysical supply and use of this service with a SEEA EA consistent methodology. The methodology focuses on measuring the biomass productivity of ecosystems suitable for livestock grazing in tonnes of biomass available for grazing by livestock. Additionally, we also aim to incorporate the estimated use of this service through incorporating spatial mapping of livestock forage demand.

This model utilizes newly available data from the Global Pasture Watch (GPW) programme (World Resources Institute Land & Carbon Lab) to map both supply and use of this service. The model incorporates global, annual 30m gross productivity data to estimate available biomass for grazing (Isik *et al.* 2024) and global, annual 1km resolution livestock density data to estimate biomass grazed (Parente *et al.* 2025). Inputs are resampled to a common resolution, with output layers generated at this resolution globally.

Initially, the approach will be inspired by the Co$ting Nature forage for livestock production model (Mulligan 2024), which has been used to map the service globally (Chaplin-Kramer *et al.* 2022). By incorporating new, higher resolution spatial data, livestock biomass intake requirements and clearer definitions of grazed lands, we aim to develop updated, annual layers.

This approach supports the production of supply and use tables aligned with SEEA EA by matching potential supply to the estimated biomass grazed.

Methodological documentation of the grazing biomass module

The approach is inspired by the Co$ting Nature forage for livestock production model (Mulligan 2024), which has been used to map the service globally (Chaplin-Kramer *et al.* 2022). By incorporating new, higher resolution spatial data (Parente *et al.* 2025), livestock biomass intake requirements (IPCC 2019) and clearer definitions of grazed lands, we produce updated, annual layers.

The complete source code is accessible at https://github.com/integratedmodelling/un.gbf.aries.
The grazing biomass-related modules are organized into 2 dedicated namespaces. One containing the script of the module, implementing the below methodology, and the other containing tables of coefficients applied in the module.

Potential supply of the service is calculated based on the annual productivity of natural/semi-natural grasslands and other land cover classes (eventually transitioning to ecosystem types) identified as suitable for livestock grazing (Parente *et al.* 2025). The alignment of these land cover classes with the IUCN GET has been elaborated in Table 3.

Grazing terminologies

The delineation of land suitable for grazing livestock will be based on several data products produced by the Global Pasture Watch. Therefore, our definitions are designed to align with these data and IUCN GET terminologies. These definitions may change slightly once the final input datasets and delineations are determined.

Cultivated/sown pastures: represented by cultivated or sown pastures and grasslands which are often heavily grazed, often in intensively managed anthropogenic systems.

Semi-managed/natural grasslands: include native vegetation and mixed species, grazed, often in extensive systems.

Other lands suitable for grazing: can include cropland/grassland mosaics, shrublands and low-density woodlands.

Forage: Plant material which is foraged or grazed by livestock. This is separate from 'fodder' which we define as feed added to the system by humans.

Figure 1. Terminologies applied in the grazed biomass modelling framework. These have been developed to align with the SEEA-EA approach as well as input datasets.

The methodology is primarily composed of 3 main components (Figure 2.): biomass production, identification of provisioning areas aligned with Indicator A2, and the demand for biomass by grazing livestock.

Supply a. Biomass production

The average annual grassland biomass production is calculated (eq. 1) based on global annual gross primary productivity (GPP) in gC/m^2/year developed by the Global Pasture Watch (GPW) consortium. These values are converted to tonnes of Dry Matter/ha/year using appropriate multipliers and the carbon to dry matter conversion factor (IPCC 2006). Light-use efficiency (LUE) factors are applied by land cover types and regions (Isik *et al.* 2024). The final grassland dry matter production values used are tonnes/ha/year (S).

$$S = s * LUE * dry\ matter\ conversion\ factor * spatial\ scale\ factor \quad (1)$$

Where s = GPP in gC/m^2/year, LUE = light use efficiency factor, dry matter conversion factor = 2.7, spatial scale factor = 0.01.

Supply b. Alignment with Indicator A2.

Natural/semi-natural grazing lands include natural/semi-natural grasslands (Parente *et. al.* 2024), shrublands and sparse vegetation land cover classes. These are assembled to constrain the biomass production input by natural/semi-natural lands. This final 'natural/semi-natural supply' represents the potential of these ecosystems to support grazed biomass provisioning.

Demand

Total annual demand (D) is estimated based on the spatial distribution of livestock, by livestock type, and their mean estimated weights by continent/region (IPCC 2019 (Table 10A.5)). Estimated daily intake (I, eq. 2) is assumed to be 2.5% of live body weight (W) (kg/head/day). The livestock headcount (LH) per cell is multiplied by I to estimate total daily demand, and by 365 and 0.001 to estimate the annual demand in tonnes/dry matter/year (Veloso *et al.* 2020).

$$I = W * 0.025 \quad (2)$$

$$D = LH * I * 365 * 0.001 \quad (3)$$

Final use

The final used service is calculated as the smallest value of the two calculations (the potential supply or the estimated use). If the intake requirement of the livestock is higher than the biomass production of the cell, it is assumed that the remainder is made up through additional supply of feed, or by managed seasonal migration of livestock (i.e., transhumance).

Calculations for the supply are carried out at approximately 100m resolution, the total supply is then aggregated to match the demand input layers (approximately 1km resolution), representing the total supply in the pixel. Final outputs are produced at approximately 1km resolution.

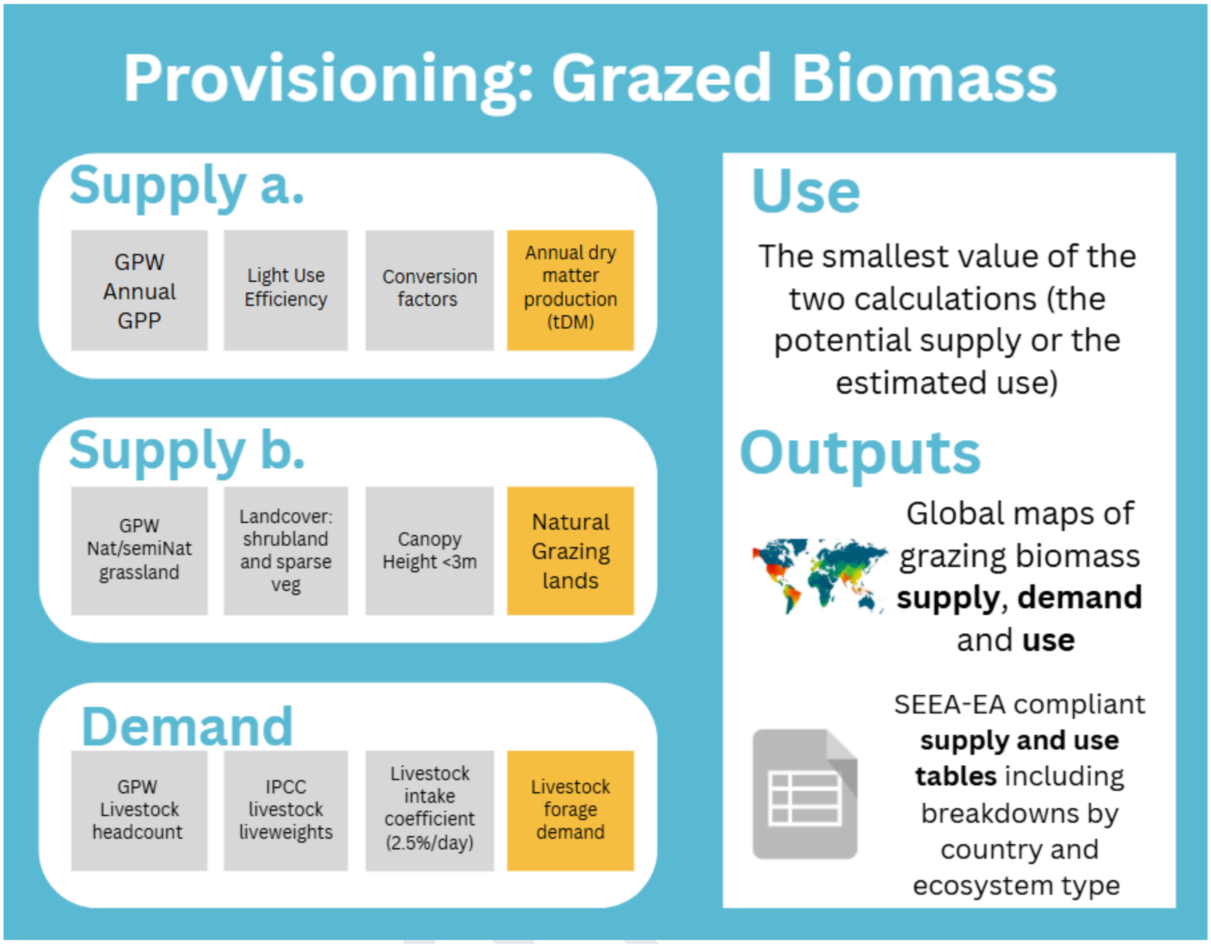

Figure 2. Input datasets and coefficients used to produce the grazed biomass provisioning maps and output tables of grazed biomass supply, demand and use. Note the methodology presented is a draft for consultation.

The module produces two outputs:

1. Maps of the potential supply provided by natural/semi-natural ecosystems that are suitable for grazing, the estimated demand of livestock, and the final estimated use of the service.
2. Results in tabular format summarizing results at the regional, national and subnational level using physical metrics for supply and use.

Data Inputs

Several global, spatial datasets are combined to estimate the availability and use of this service (See Table 2). Where possible, annual products are used to ensure granularity and the ability to monitor changes over time. Modeling parameters derived from these datasets include:

1. Annual average dry matter productivity (derived from the GPW GPP dataset, Isik *et al.* 2024)
2. Spatial distribution of grazing lands: Distribution of cultivated (i.e., sown pastures) and natural/semi-natural grasslands (Parente *et al.* 2024), as well as shrublands, and sparse vegetation. This is estimated by combining maps of natural and semi-natural grasslands, shrublands and sparse vegetation and applying constraints (such as vegetation height).
3. Distribution of livestock (GPW dataset, Parente *et al.* 2025). Global 1km resolution annual layers for the distribution of livestock types including cattle, sheep, goats and horses. FAO-STAT adjusted headcounts per grid cell are used. These are developed from nationally reported statistics in livestock census data, integrated with land cover, and factors known to drive the presence of livestock (such as access to markets, religious practices, land surface temperature and elevation.
4. Land cover data (Zhang *et al.* 2023) to identify non-grassland grazing lands (such as shrublands and sparse vegetation). When available, spatially explicit data on ecosystem types relevant to the service will be preferred.

Table 2. Dataset inputs to the grazed biomass provisioning model.

Dataset	Description	Producer	Purpose	Temporal coverage	Spatial resolution
Annual Dominant Class of Grasslands	Global grassland extent is classified into two classes: Natural/Semi-natural and cultivated grasslands.	Global Pasture Watch (Land & Carbon Lab, World Resources Institute)	Delineate grassland extent, identifying grassland considered natural/semi-nature vs sown and managed pastures.	Annual (2000-2022). Further annual updates expected	30m
GLC_FCS30D Global 30-meter Land Cover Change Dataset (1985-2022)	Global land cover layer classified into 35 land cover classes.	Zhang *et al.* (2024)	Delineate non-grassland grazed ecosystems, including shrublands and sparse vegetation. Currently forests and croplands are excluded.	Annual (1985-2022). Further updates TBC	30m
Annual uncalibrated Gross Primary Productivity (uGPP)	This dataset provides global uncalibrated EO-based Gross Primary Productivity, annually.	Global Pasture Watch (Land & Carbon Lab, World Resources Institute)	Estimate annual biomass available for grazing. Units are converted from gC/m^2/year to tonnes dry matter/ha/year. Values within grassland are adjusted for light use efficiency.	Annual (2000-2022). Further annual updates expected	30m
Livestock Headcount, annual, 1-km	Spatially disaggregated livestock census data using environmental predictors. The dataset represents headcounts for cattle, sheep, goats and horses are estimated and adjusted to match national statistics in FAOSTATs.	Global Pasture Watch (Land & Carbon Lab, World Resources Institute)	Estimate number of livestock grazing per cell (demand for the service)	Annual (2000-2022). Further annual updates expected	1-km

Notes on the global runs

This analysis covers 2020 and subsequent years where there are data available. Because this approach uses annual data, as opposed to longer average trends, some changes may be the result of annual 'noise' in the data where cells 'flip-flop' between years. Additionally, this analysis is constrained to areas identified as being representative of natural/semi-natural ecosystems. Therefore, some regions/countries may appear to have low potential for the service, despite high demand. In these cases, it is assumed that supply from managed ecosystems (such as pastures) and imports are used to meet un-met demand.

Acknowledgements

We would like to thank Steven King, Mandy Driver and all members of the SEEA-EA task force for their inputs and advice during the development of this module. We would also like to thank Lindsey Sloat (WRI), Serkan Isik (OpenGeoHub Foundation), Laerte Guimaraes Ferreira (UFG) for their support in utilising the latest Global Pasture Watch datasets and review of the module, and Mark Mulligan (Kings College London) and Arnout van Soesbergen (UNEP-WCMC) for their review of the module. All feedback and support was greatly appreciated.

References

Arantes, A. E., Couto, V. R. de M., Sano, E. E., and Ferreira, L. G. (2018). Livestock intensification potential in Brazil based on agricultural census and satellite data analysis. *Pesquisa Agropecuaria Brasileira*, 53(9), 1053–1060. https://doi.org/10.1590/S0100-204X2018000900009

Chaplin-Kramer, R., Neugarten, R.A., Sharp, R.P. *et al.* (2023). Mapping the planet's critical natural assets. *Nat Ecol Evol*, 7, 51–61. https://doi.org/10.1038/s41559-022-01934-5

Driver, A. & Botts, E.A. (Eds.) (2025). Guidelines for classifying agricultural and plantation forestry ecosystems in the IUCN Global Ecosystem Typology. Gland, Switzerland: IUCN.

IPCC (2019). "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories." Switzerland: IPCC.

Isik, M.S., Parente, L., Consoli D. *et al.* (2024). Light Use Efficiency (LUE) based bimonthly Gross Primary Productivity (GPP) for global grasslands at 30 m spatial resolution (2000-2022), PREPRINT (Version 1) available at Research Square [https://doi.org/10.21203/rs.3.rs-5587863/v1]

Mulligan (Feb 9, 2024 update). Documentation for the Co$tingNature Model V3. www.policysupport.org/costingnature. Original V3 documentation 2017.

Parente, L., Sloat, L., Mesquita, V., Consoli, D., Stanimirova, R., Hengl, T., Bonannella, C. *et al.* (2024). "Global Pasture Watch - Annual Grassland Class and Extent Maps at 30-m Spatial Resolution (2000—2022)". Zenodo, https://doi.org/10.5281/zenodo.13890417.

Parente, L., Ehrmann, S., Hengl, T., Fritz, S., Bonannella, C., Malek, Ž., Fischer, C., Perez-Guzman, K., Stanimirova, R., Meyer, C., Wisser, D., Cinardi, G. and Sloat, L. (2025). Global distribution of cattle, goats, sheep and horses at 1-km resolution for 2000-2022 based on sub-national census data and spatiotemporal Machine Learning. 10.21203/rs.3.rs-6201916/v1.

United Nations (2024). System of Environmental-Economic Accounting: Ecosystem Accounting. Accessed at: https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_f124_web_12dec24.pdf

Veloso,G.A., Ferreira, M.E., Ferreira Júnior, L.G., Barbosa da Silva.B. (2020). Modelling gross primary productivity in tropical savanna pasturelands for livestock intensification in Brazil, Remote Sensing Applications: Society and Environment, 17, 100288, ISSN 2352-9385, https://doi.org/10.1016/j.rsase.2020.100288.

Willcock, S., Hooftman, D.A.P., Neugarten, R., Chaplin-Kramer, R., Barredo, J.I., Hitler, T., Kindermann, G., Lewis, A.R., Lindeskog, M., Martínez-López, J. and Bullock, J.M. (2023). Model ensembles of ecosystem services fill global certainty and capacity gaps. *Sci. Adv*. 9,. DOI:10.1126/sciadv.adf5492

Zhang, X., Zhao, T., Xu, H., Liu, W., Wang, J., Chen, X., and Liu, L. (2024). GLC_FCS30D: the first global 30 m land-cover dynamics monitoring product with a fine classification system for the period from 1985 to 2022 generated using dense-time-series Landsat imagery and the continuous change-detection method. *Earth Syst. Sci. Data*, 16, 1353–1381, https://doi.org/10.5194/essd-16-1353-2024.