GHG Emissions Assessment of Climate-Resilient Livestock Farming

Majid Iravani

Alberta Biodiversity Monitoring Institute, University of Alberta,
iravani@ualberta.ca

Dec 8, 2022; UB, Mongolia

Presentation Outline

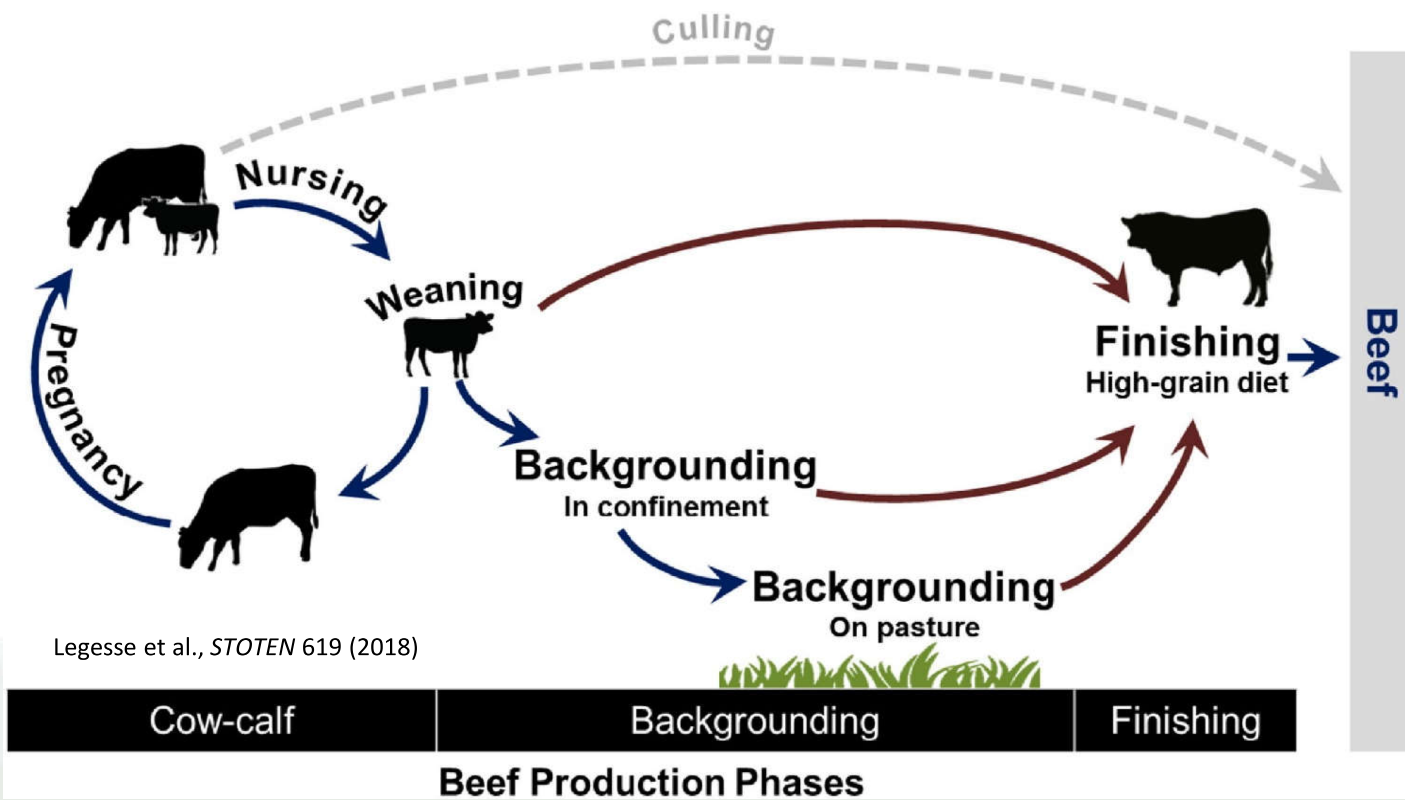
- Livestock Life Cycle Impact Assessment
- Existing Methodologies and Data and Information Needs
- GHG Assessment in Bayantumen Soum
- Open Discussion

Livestock Life Cycle Impact Assessment

All sources of emissions along the livestock supply chain

Total emissions for a given farming system or emissions per unit of a single product or combinations of different commodities/farming systems/locations at different spatial scales.

Livestock farming: All processes up to the farmgate where the animals or products leave the farm.



Legesse et al., *STOTEN* 619 (2018)

Livestock Life Cycle Impact Assessment

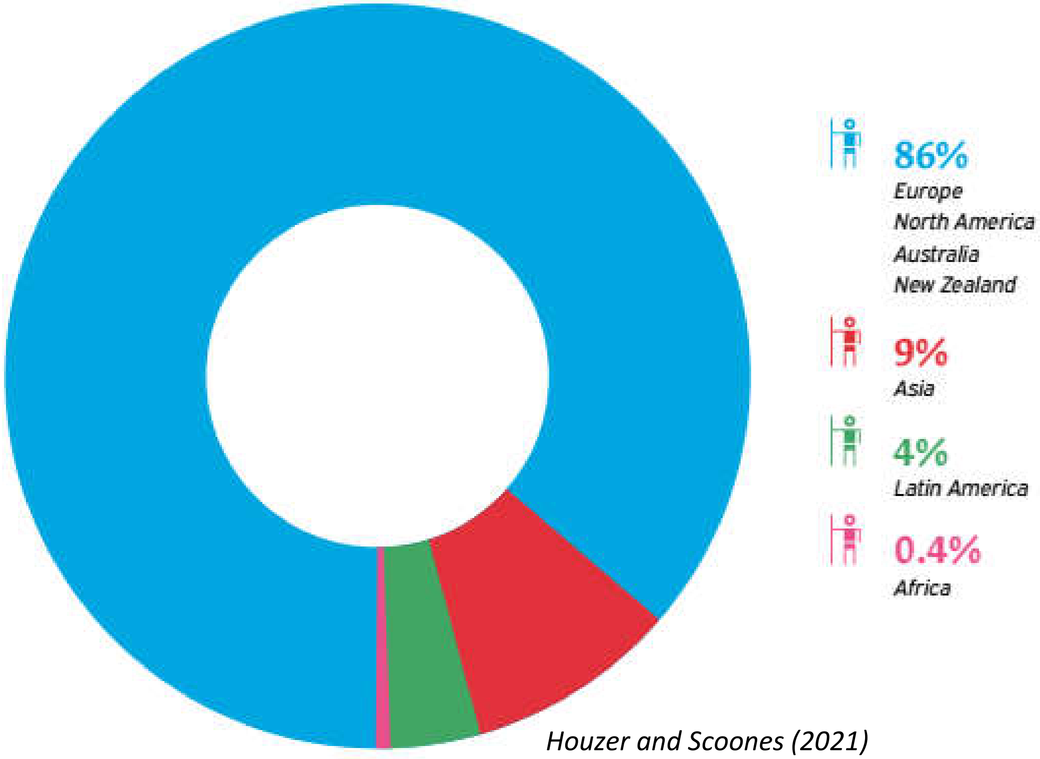
LCAs draw on data from high-income countries, where agricultural systems are more industrialized.

The perspectives of nutritionally vulnerable, poor populations are often missing or underrepresented in scientific analyses.

Assumptions embedded in many Life Cycle Analyses lead to an overestimation of emissions from extensive livestock settings.

An assumption of many LCA assessments is that the abandonment of livestock extensive systems would result in beneficial, ‘land-sparing’ rewilding/ regeneration of the land, allowing more effective carbon sequestration.

Regions covered by 164 life cycle analysis



Houzer and Scoones (2021)

GHG Emissions Assessment Approaches

The IPCC presents a 3-tiered classification of methodological approaches to GHG emissions quantification

Approach	Method	Data Requirements	Aggregation Level/ Uncertainty	Notes
Tier 1 Empirical Model	IPCC Tier 1 default equations and factors (FAO-LEAP Level 1 model)	Limited land use and management activity data, little soil delineation and vegetation types; no requirement for model calibration and validation; least data input/output complexity	Typically, large spatial units; National scale; annual resolution	Suitable for rough overviews and where only limited data is available)
Tier 2 Model	Similar to Tier 1 approach with regionally specific empirical factors or with factors derived from validated process models	Intermediate spatial/temporal scale input data; land use and activity data stratified; intermediate requirement for model development and validation; modest data input/output complexity	Finer spatial and temporal resolution than Tier 1; can achieve reasonable uncertainty when good amount and quality of empirical data are used for model development.	Suitable for roll-ups to regional to national scale; can be suitable for project-based, farm-specific accounting.
Tier 3 Measurement	Amount and change by periodic measurement only	Spatial data on soils, land use, land management, vegetation, climate for stratification in carbon estimation areas, annual land management, data from periodic soil sampling; high data complexity	Spatial scale depends on sampling plan, can be coarse or very fine; capable of lowest uncertainty possible for quantification	Most costly to implement

Viresco Solutions Inc. (2020)

GHG Emissions Assessment Tools and Data Requirements

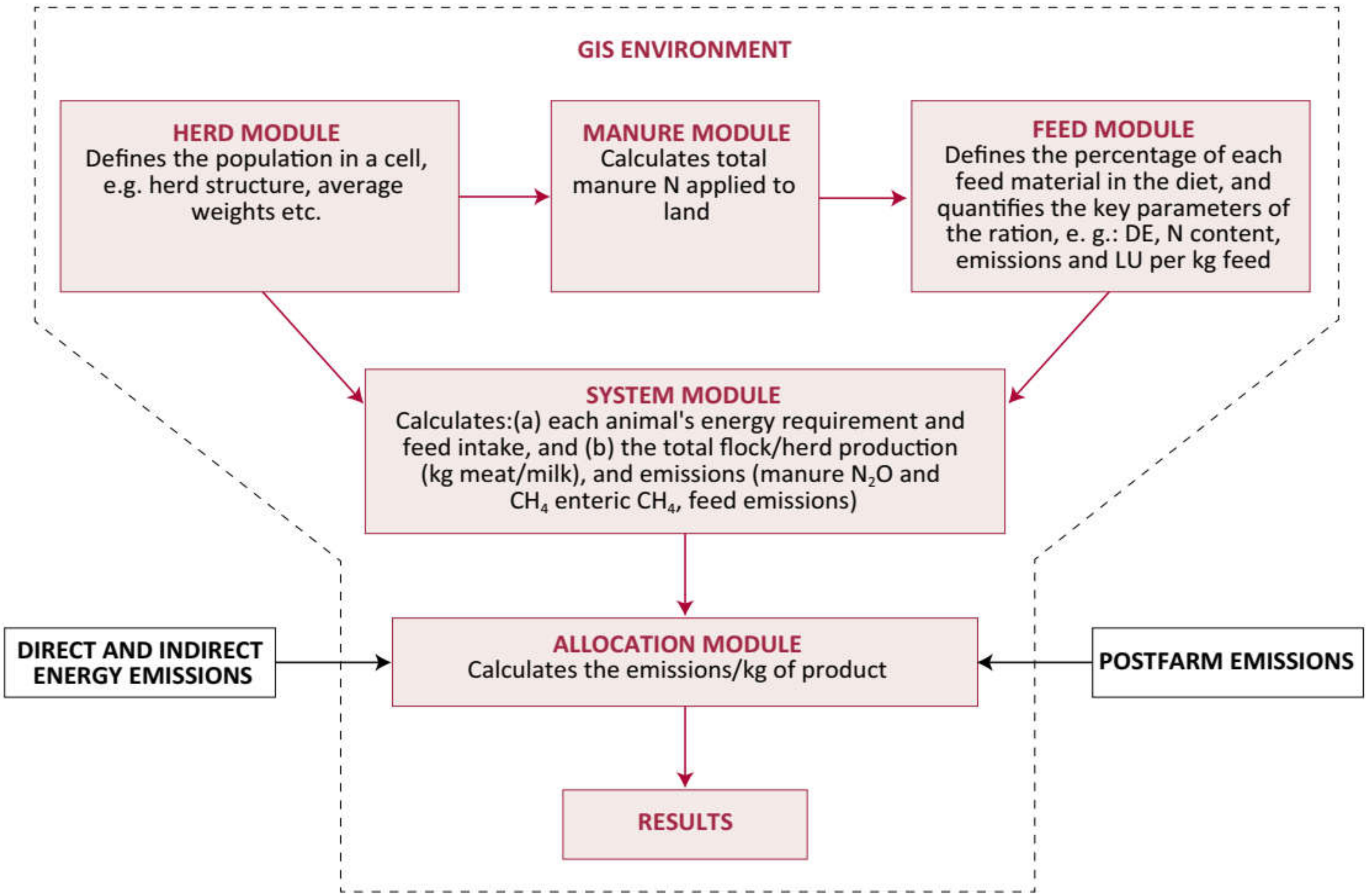
Name of Calculator/tool	Linkage between SOC and other sources and sinks	Transparency	Focus
APSIM	Modular format allows linkage with other models. Crop Livestock Enterprise Model (CLEM) is a module for modeling grassland and livestock productivity and resource use using the APSIM platform.	Detailed reports for each crop type, module, and underlying data for defaults. Available publicly.	Cropping systems in temperate and tropical regions – grains, fibers. CLEM focus is farm resource management rather than a SOC model. Focus on farm managers, agronomists, and researchers.
Cool Farm Tool	SOC available for perennial grass and forage crops in the crop module. Crop footprints can be linked with the livestock module.	Detailed methods documents are available to members. Methods follow IPCC. The origin of some default factors is more difficult to obtain.	Whole farm assessment, ease- of-use for the farmer, but increasingly used as a supply chain GHG calculator at scale. Includes SOC stock estimates from Open Land map datasets but does not integrate this data with calculations yet. Includes Land Use Change.
Holos	The whole farm approach integrates livestock emissions with SOC.	A good set of references available publicly. Transparency of methods and underlying data and assumptions likely available to Canadian users.	Specifically designed for whole-farm assessments in Canada. More widely used by researchers and agrologists than farmers.
Canada National Inventory Report	Comprehensive for Canada is divided into subregions and then into categories and subcategories of emissions.	Methods are well documented and comparable with that of other countries	National estimates

SOC: Soil Organic Carbon

Viresco Solutions Inc. (2020)

GHG Emissions Assessment Tools and Data Requirements

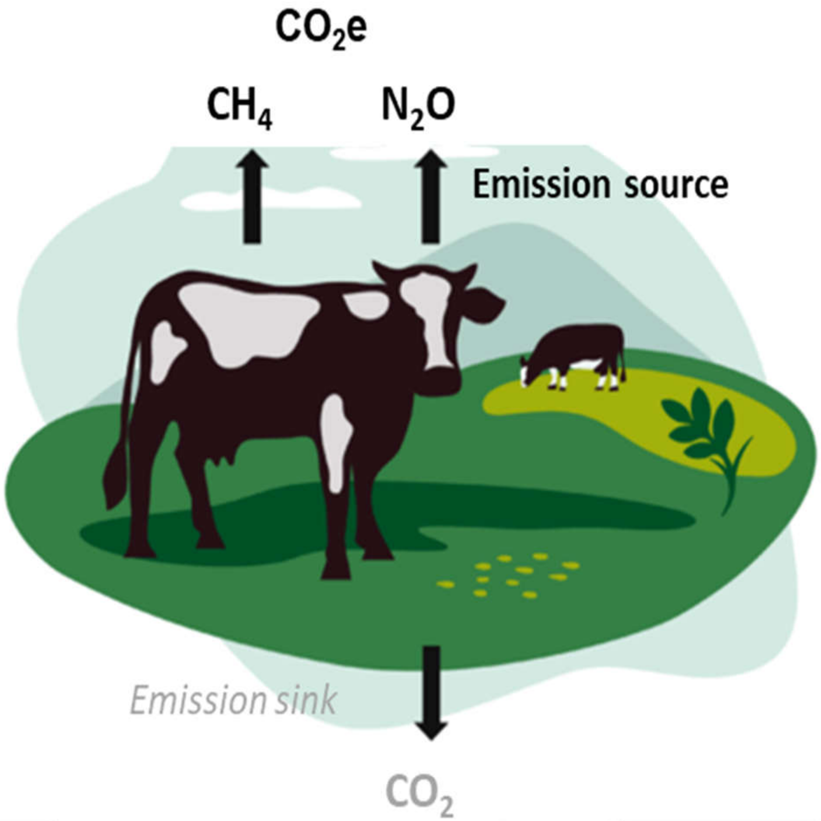
Global Livestock Environmental Assessment Model (GLEAM)



Opio et al., 2013, FAO

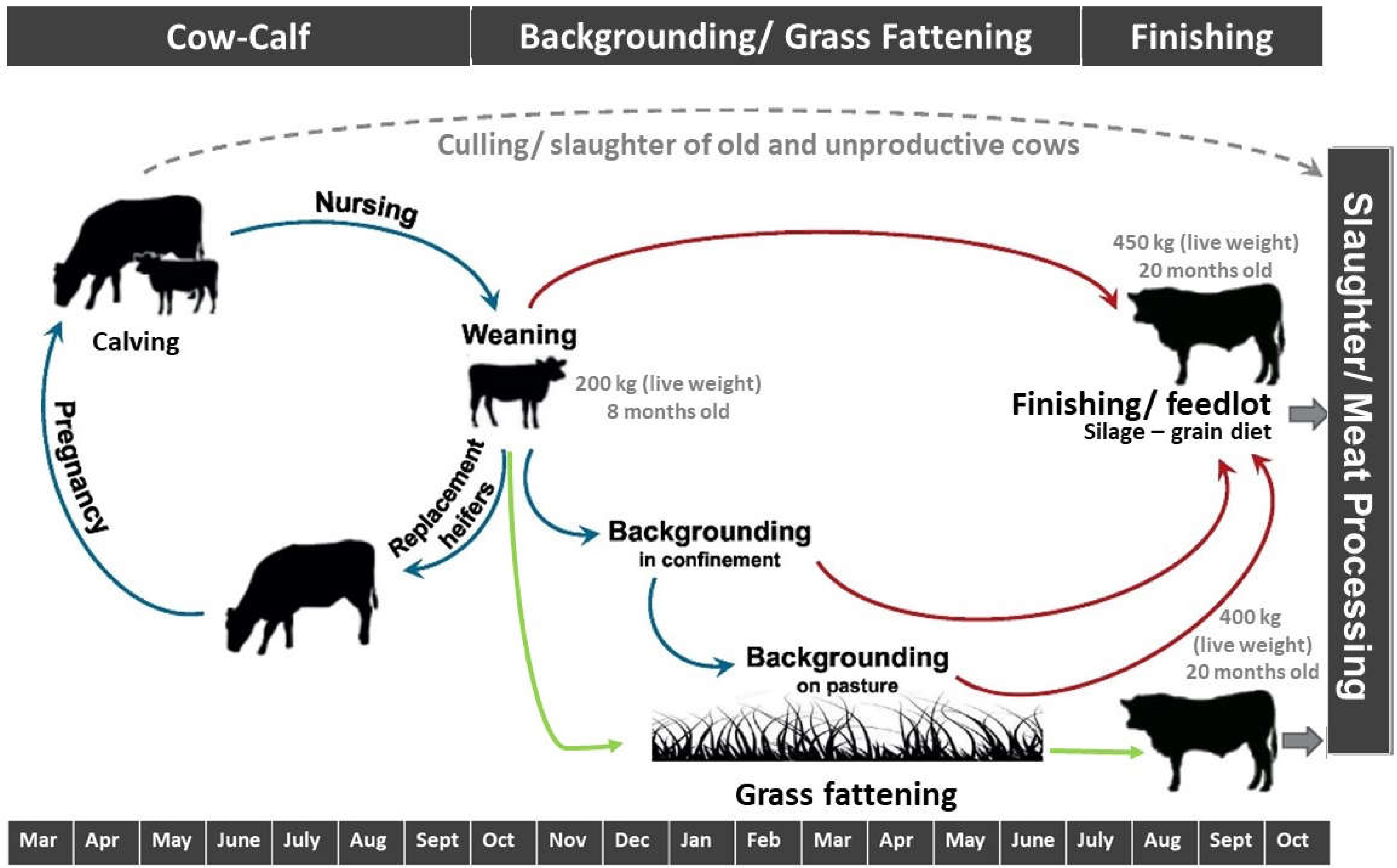
GHG Emissions from Improved Local Livestock Farming

- GHG emissions from enteric fermentation and livestock waste.
- Assuming no grazing and haymaking-induced CO_2e emission and loss from pasture and cultivated soils.
- Assuming an average climate and livestock-marketing year
- Based on the best available data from open-access studies and datasets



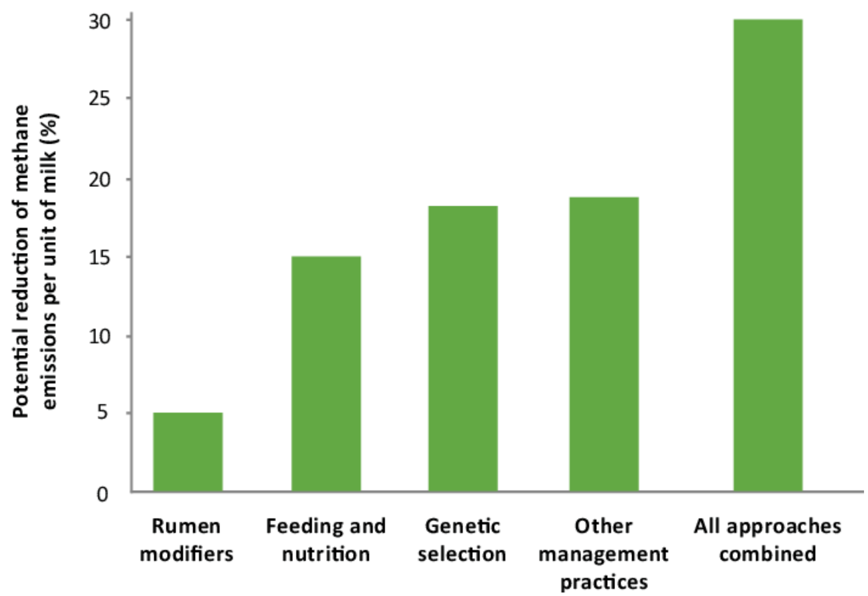
GHG Emissions from Improved Local Livestock Farming

Effects of cattle herd and sheep flock restructuring scenarios for average herder households.

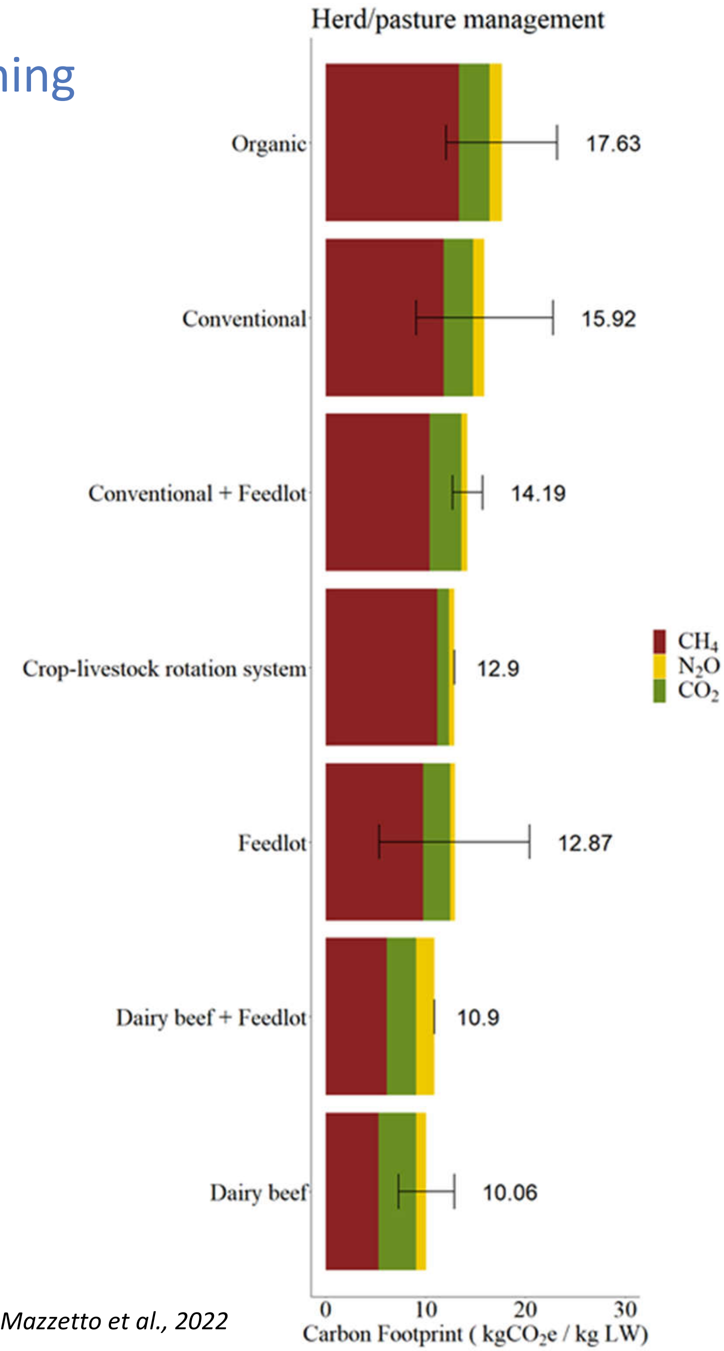


GHG Emissions from Improved Local Livestock Farming

GHG emission reduction effects from improved grazing, pasture, and livestock productivity.



Aguirre-Villegas et al., 2017. Sustainabledairy.org



Mazzetto et al., 2022

1) Conventional: mostly grass-based management (included extensive/intensive management with/without the use of supplementary feeds)
2) Feedlot: animals are on a feedlot after weaning
3) Organic: organic production systems
4) Dairy-beef: beef derived from dairy animals
5) Crop-livestock rotation system: land is rotated between different crops and pasture over time.

GHG Emissions from Improved Local Livestock Farming

Realistic ranges (min and max) of GHG emission intensity or kg of CO_2e per head of adult livestock per year from relevant studies and tools (e.g., GLEAM and LEAP).

Cattle types	Current - 20 Adult Cows							GHG Emission					
	Total Aug	CUs Aug^	Total Sold (Dec)	Average Live weight (kg)	Total Live weight (kg)	Price (MNT/kg)	Total Value (1000 MNT)	Intensity (kg CO2e/head/yr)		Total (kg CO2e/yr)		kg CO2e/kg live weight	
								Min	Max	Min	Max	Min	Max
Adult cows (42 months and older)	20	20	2	450	900	3000	2700	1731	2398	34620	47960		
Calves (born in spring)	19	6	0				0	1731	2398	10963	15187.33333		
Yearlings (16-18 months old)	18	9	0				0	1731	2398	15579	21582		
Steers (30 months old)	8	8	0				0	1731	2398	13848	19184		
Replacement heifers (30 months old)	8	8	0				0	1731	2398	13848	19184		
Non-pregnant replacement heifers (34 months old)	0	0	0				0	1731	2398	0	0		
Steers (42 months old)	8	8	0				0	1731	2398	13848	19184		
Steers (54 months old)	7	7	7	450	3150	3000	9450	1731	2398	12117	16786		
Bull for breeding	1	1	0				0	1731	2398	1731	2398		
Open cows (48 months and older)	3	3	1	450	450	3000	1350	1731	2398	5193	7194		
Total	92	70	10		4500		13500	1731	2398	121747	168659	27.1	37.5

^ 3 calves considered as one adult cow and 2 yearlings considered as one adult cow. The rest of the herd considered as 1 adult cow.

GHG Emissions from Improved Local Livestock Farming

Overall GHG emissions for cattle and sheep meat production in grass-finished and mixed operation (a combination of pastures and creep feeding or feedlots).

Cattle types	With Project - 40 Adult Cows (calves sold at weaning)							Feedlot-finished-only herd restructuring					
	Total Aug	CUs Aug^	Total Sold (Dec)	Average Live weight (kg)	Total Live weight (kg)	Price (MNT/kg)	Total Value (1000 MNT)	Intensity (kg CO2e/head/yr) Min	Intensity (kg CO2e/head/yr) Max	Total ((kg CO2e) Min	Total ((kg CO2e) Max	kg CO2e/kg live weight Min	kg CO2e/kg live weight Max
Adult beef cows (42 months and older)	35	35	4	450	1800	3000	5400	1731	2398	60585	83930		
Adult milk cows (42 months and older)	5	5	0				0	1731	2398	8655	11990		
Calves (born in spring)	40	40	35	450	15750	3000	47250	1731	2398	69240	95920		
Replacement heifers (18 months old)	5	5	0				0	1731	2398	8655	11990		
Replacement heifers (30 months old)	5	5	0				0	1731	2398	8655	11990		
Non-pregnant replacement heifers (34 months old)	1	1	1	350	350	3000	1050	1731	2398	1731	2398		
Bull for breeding	2	2	0				0	1731	2398	3462	4796		
Total	93	93	40		17900		53700			160983	223014	9.0	12.5

GHG Emissions from Improved Local Livestock Farming

GHG emission reduction effects from improved grazing, pasture, and livestock productivity.

Grass finished Herd restructuring & Pasture/grazing improvement								Grass finished Herd restructuring & livestock improvement							
Pasture improvement Factor (-)		Adjusted Intensity (kg CO2e/head/yr)		Total (kg CO2e)		kg CO2e/kg live weight		Livestock improvement Factor (-)		Adjusted Intensity (kg CO2e/head/yr)		Total ((kg CO2e)		kg CO2e/kg live weight	
Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
30.1	8.3	1210	2199	42349	76964			14.0	9.2	1489	2177	52103	76208		
30.1	8.3	1210	2199	6050	10995			14.0	9.2	1489	2177	7443	10887		
30.1	8.3	1210	2199	48399	87959			14.0	9.2	1489	2177	59546	87095		
30.1	8.3	1210	2199	6050	10995			14.0	9.2	1489	2177	7443	10887		
30.1	8.3	1210	2199	6050	10995			14.0	9.2	1489	2177	7443	10887		
30.1	8.3	1210	2199	1210	2199			14.0	9.2	1489	2177	1489	2177		
30.1	8.3	1210	2199	2420	4398			14.0	9.2	1489	2177	2977	4355		
				112527	204504	8.9	16.2					138445	202497	10.9	16.0

GHG Emission from Herd Restructuring

- A herder can raise 40 cows, sells steers when weaned and maintain fewer cattle over the winter.
- A herder can earn 27.4 million MNT by selling weaned calves compared to only earning 13.5 million MNT under traditional management.
- A herder can drop the annual rate of GHG emission by up to 23 % by moving to a cow-calf operator or calf supplier.
- A herder can drop the GHG emission rate per unit live weight of cattle remarkably, in particular when pasture and livestock productivity improved.

Cattle Herd management	Operation	GHG Emission							
		Total (tCO_2e/yr)		Rate ($kgCO_2e/kg$ live weight)		Change in Total (tCO_2e/yr)		Change in Rate ($kgCO_2e/kg$ live weight)	
		Min	Max	Min	Max	Min	Max	Min	Max
Current (20 adult cows)	Traditional	122	169	27	38	-	-	-	-
Restructured (40 adult cows)	Cow-calf	109	151	12	17	-13	-18	-15	-21
	Grass-finished	161	223	13	18	39	54	-14	-20
	Feedlot-finished	145	201	8	11	23	32	-19	-26
Restructured & grazing/pasture improved	Cow-calf	76	139	8	15	-46	-30	-19	-22
	Grass-finished	113	205	9	16	-9	36	-18	-21
	Feedlot-finished	101	184	6	11	-21	15	-21	-26
Restructured & livestock productivity improved	Cow-calf	94	137	10	15	-28	-32	-17	-23
	Grass-finished	139	203	11	16	17	34	-16	-22
	Feedlot-finished	101	176	6	10	-21	7	-22	-28

GHG Emission from Herd Restructuring

- A herder can raise 100 sheep, sell lambs in the fall when they are 8-9 months of age and maintain fewer sheep over the winter.
- A herder can earn 10.2 million MNT by selling weaned calves compared to earning 9 million MNT under traditional management.
- A herder can drop the annual rate of GHG emission by up to 43 % by moving to a ewe-lamb operator or lamb supplier.
- A herder can drop the GHG emission rate per unit live weight of sheep remarkably, in particular when pasture and livestock productivity improved.

Sheep Flock Management	Operation	GHG Emission							
		Total (tCO_2e/yr)		Rate ($kgCO_2e/kg$ live weight)		Change in Total (tCO_2e/yr)		Change in Rate($kgCO_2e/kg$ live weight)	
		Min	Max	Min	Max	Min	Max	Min	Max
Current (100 ewes)	Traditional	118	168	17	25	-	-	-	-
Restructured (100 ewes)	Grass-finished	81	115	11	15	-37	-53	-7	-10
	Feedlot-finished	73	104	9	12	-45	-64	-9	-13
Restructured & grazing/pasture improved	Grass-finished	56	106	7	14	-61	-62	-10	-11
	Feedlot-finished	51	98	6	11	-67	-70	-12	-14
Restructured & livestock productivity improved	Grass-finished	63	108	8	14	-55	-60	-9	-11
	Feedlot-finished	51	91	6	11	-67	-77	-12	-14

GHG Mitigation Capacity of Local Livestock Farming

If no adaptive measures are taken to prevent and remove additional livestock from the landscape and rehabilitate soil and vegetation of degraded pastures in the soum, then in the year 2025 alone, an estimated total GHG emission removal opportunity of 479 to 1010 thousand tons of CO_2e from the soum's livestock sector will be missed. This would roughly equal annual carbon removal by 23.9 to 50.5 thousand trees (20 kg CO_2e/yr removal by a single young tree).

Description	Scenario	Year	Livestock Types					
			Horse	Cattle	Camel	Sheep	Goat	Total
Livestock Population (10^3 heads)	Historic	2017	25.1	17.6	0.7	70.1	45.6	159.0
		2021	38.4	30.9	0.9	109.8	69.5	249.6
	Change (%)	2017-2021	53.2	76.1	36.8	56.7	52.4	57.0
	Projected	2025	58.8	54.4	1.3	172.1	106.0	392.6
	Optimized*	2025	38.4	24.7	0.9	76.9	69.5	210.5
GHG intensity (tCO_2e/head/yr)!			0.91	2.06	1.61	0.26	0.23	-
GHG emission (10^3tCO_2e/yr)	Historic	2017	22.7	36.2	1.1	17.9	10.4	88.3
		2021	34.8	63.8	1.5	28.0	15.9	143.9
	Projected	2025	53.3	112.4	2.1	43.9	24.2	235.7
	Optimized	2025	34.8	51.1	1.5	19.6	15.9	122.8
GHG emission change (10^3tCO_2e/yr)	Historic	2017-2021	**12.1**	**27.6**	**0.4**	**10.1**	**5.5**	**55.6**
	Projected	2021-2025	**18.5**	**48.6**	**0.6**	**15.9**	**8.3**	**91.8**
	Historic - Optimized	2021-2025	**0.0**	**-12.8**	**0.0**	**-8.4**	**0.0**	**-21.2**
	Projected - Optimized	2025-2025	**-18.5**	**-61.3**	**-0.6**	**-24.3**	**-8.3**	**-113.0**

! Values are based on Shi et al., 2022 (Front. Public Health, 11).

Conclusions and Limitations

- This preliminary assessment demonstrates the potential GHG emission and removal from the traditional livestock sector in the Bayantumen Soum.
- It demonstrates how restructuring the existing livestock herds and improvement in grazing and livestock management can potentially increase the GHG emission efficiency of livestock products while increasing the total production of livestock live weight for an average herder household.
- While great care has been taken to ensure that the input data and the results were of the highest quality possible, there remain several limitations in the underlying datasets and therefore projected changes.
- These results provide a basis for identifying adaptation pasture and livestock management measures that target the mitigation of GHG emissions from the livestock sector.
- However, they also suggest that more effort needs to be put into a systematic assessment of the sector's potential GHG emissions and removal.
- This includes considering the IPCC Guidelines Tier 3 methods that require locally appropriate emission factors for different livestock types and practices that can be obtained though direct measurement of GHG emissions from different aspects and stages of the livestock life cycle.

Swainson's Hawk
(*Buteo swainsoni*)

Picture: ABMI NatureLynx

Questions and feedback

Majid Iravani

Alberta Biodiversity Monitoring Institute

University of Alberta

E-mail: iravani@ualberta.ca

It's Our Nature *to Know*

Alberta Biodiversity Monitoring Institute