Carbon Sequestration Assessment of Climate-Resilient Livestock Farming

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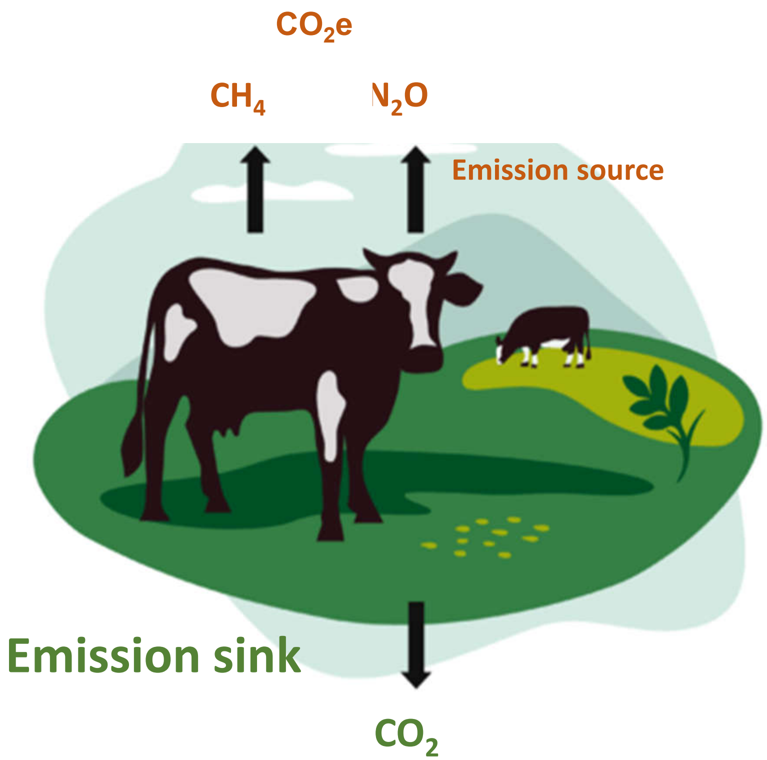
It's Our Nature *to Know*
Alberta Biodiversity Monitoring Institute

Presentation Outline

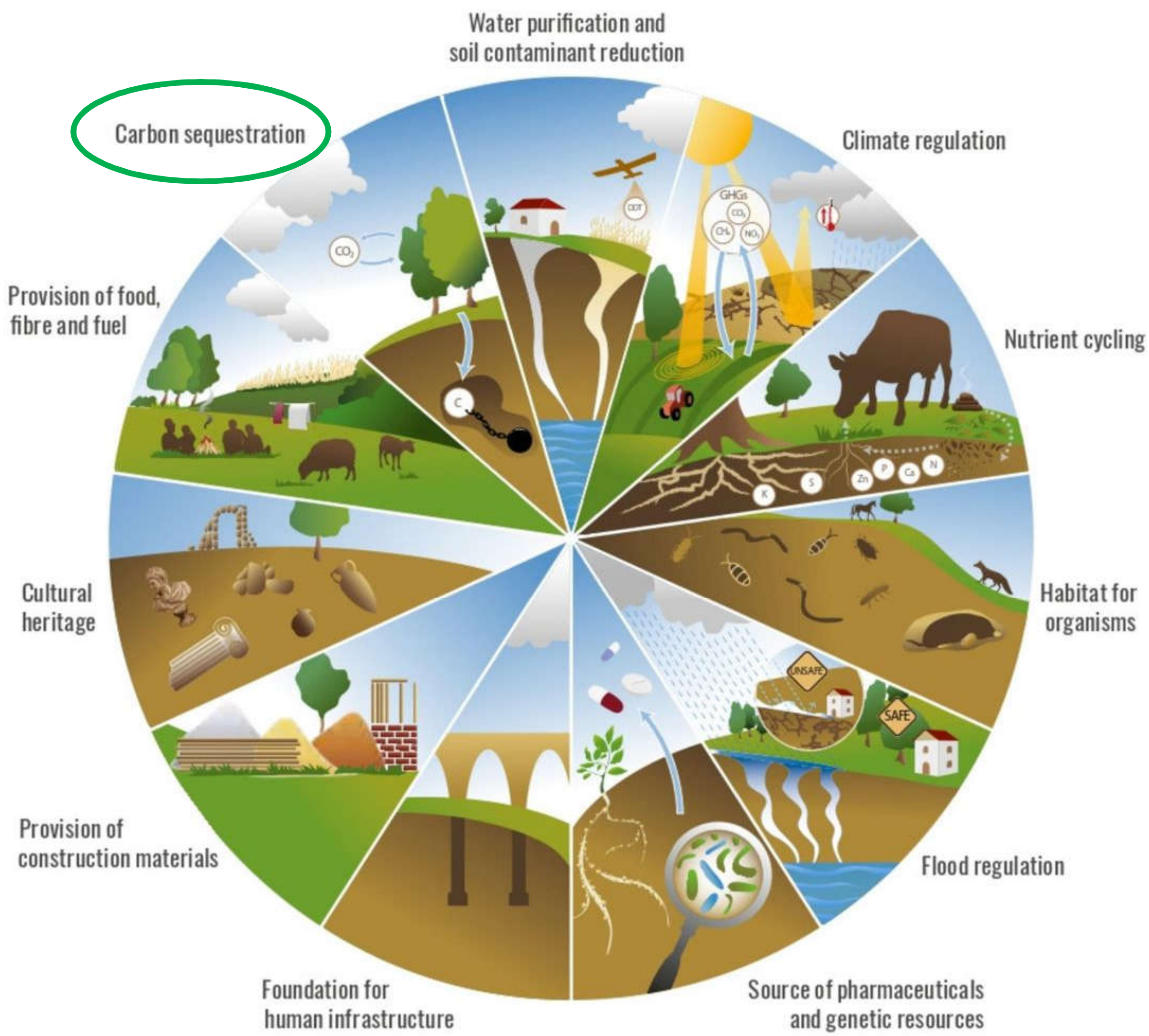
- Introduction
- Carbon Sequestration, Carbon Stock and Carbon Stock Changes
- Existing Methodologies and Data and Information Needs
- Carbon Sequestration Assessment in Bayantumen Soum
- Open Discussion

Emission Sink and Emission Source

- A **carbon sink** is anything that absorbs more carbon from the atmosphere than it releases.
- A **carbon source** is anything that releases more carbon into the atmosphere than it absorbs.



Carbon Sequestration



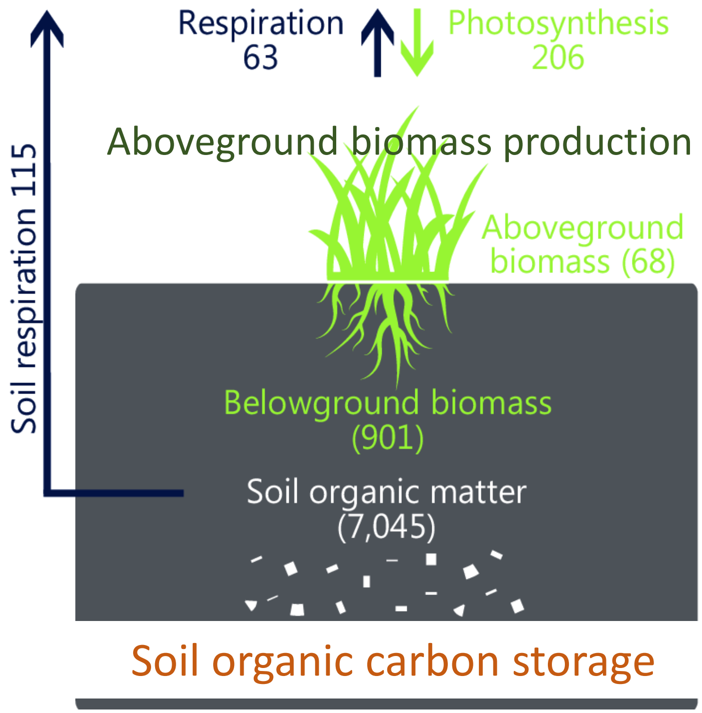
Source: adapted from FAO. 2015. *Soils deliver ecosystem services that enable life on Earth – Infographics.* https://www.fao.org/publications/card/en/c/0815e457-c6a4-47e9-ab6c-f23224279834

Soil carbon sequestration is a process whereby CO_2 is removed from the atmosphere by vegetation, and stored in the soil's pool of organic carbon

Carbon sequestration results from the interactions of several ecosystem processes, of which photosynthesis, respiration, and decomposition are key.

Carbon Sequestration and Organic Carbon Stocks

Grassland Organic Carbon Stocks



Carbon storage (in parentheses): g/m^2
Carbon fluxes (arrows): g/m^2/day

Janowiak et al. 2017; Burke et al. 2008

Soil organic matter is a heterogeneous mixture of soil microbes including bacteria and fungi, decaying material from once-living organisms such as plant and animal tissues, fecal material, and products formed from their decomposition (fresh plant residues to highly decomposed material or humus).

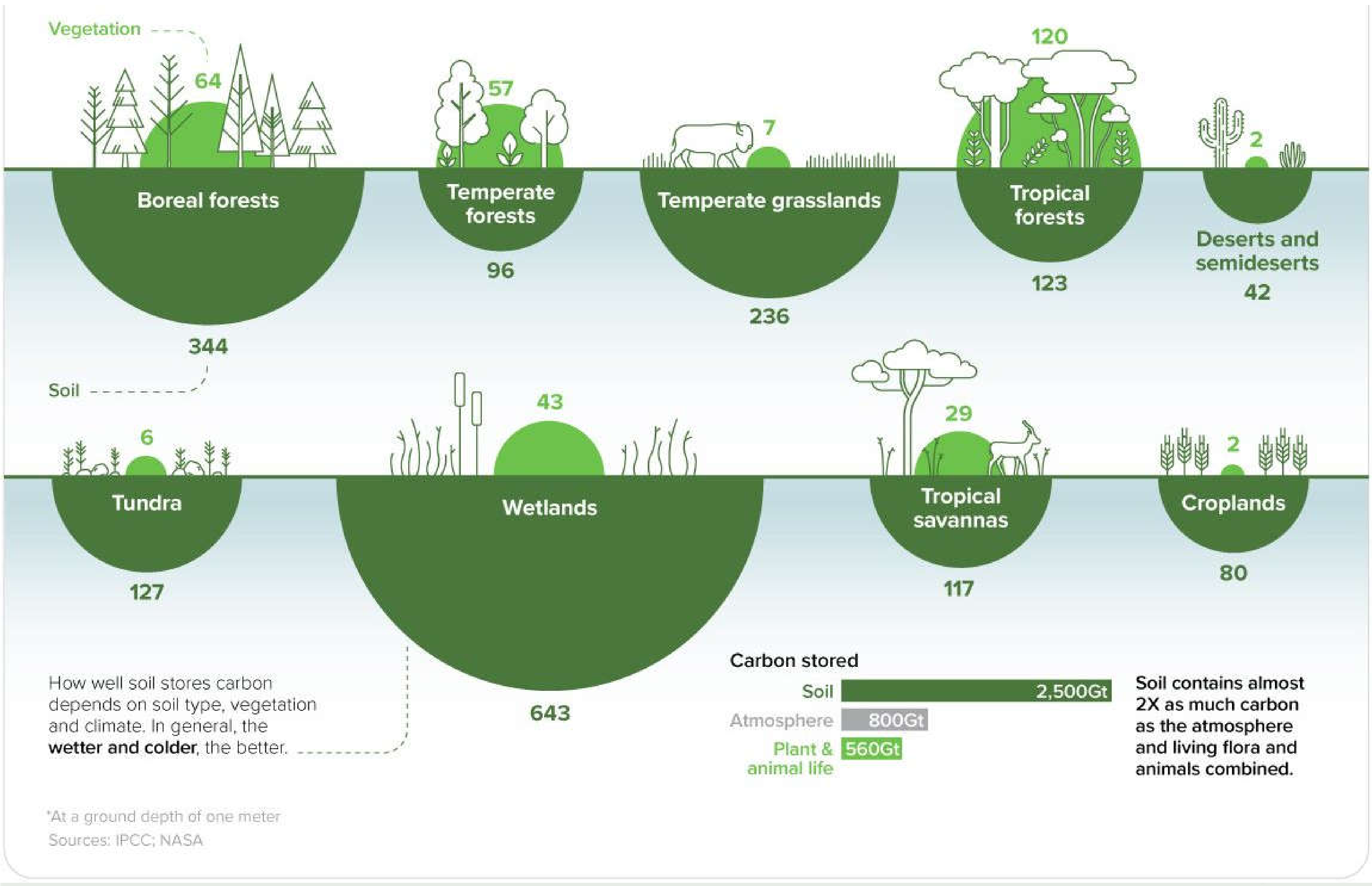
Soil organic carbon (SOC) is directly related to the amount of organic matter contained in soil and SOC is often how organic matter is measured in soils.

Organic matter (%) = Total organic carbon (%) x 1.72 or 1/0.58

Organic Carbon Stocks are total organic carbon stored in a grassland system.

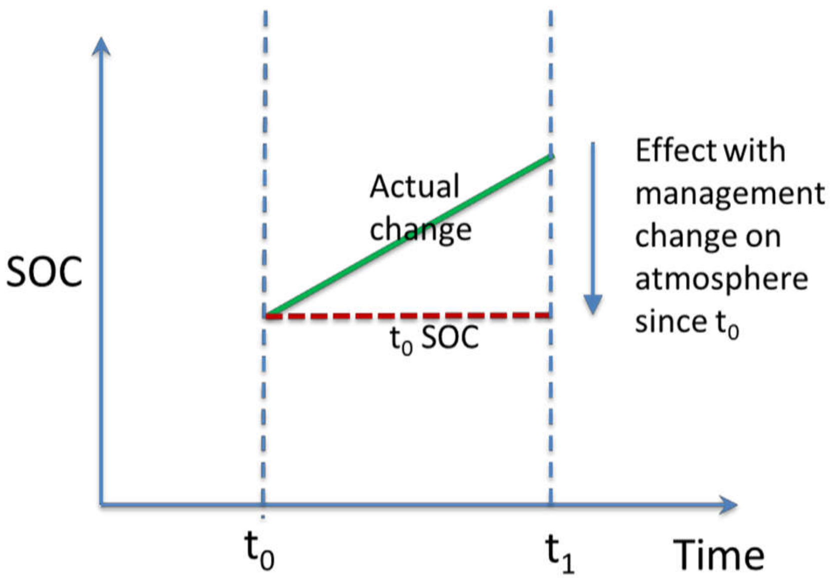
It is much easier to estimate carbon stocks to a given relative accuracy than carbon stock changes to that same accuracy.

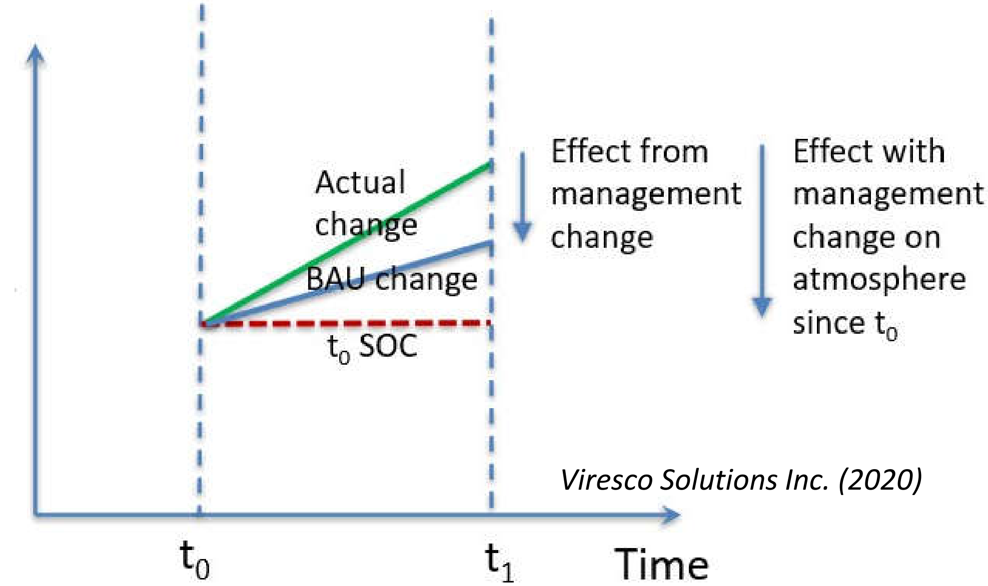
Organic Carbon Stocks in Different Landscapes



Carbon Stock Change Assessment

It's important to consider what SOC change is to be measured!





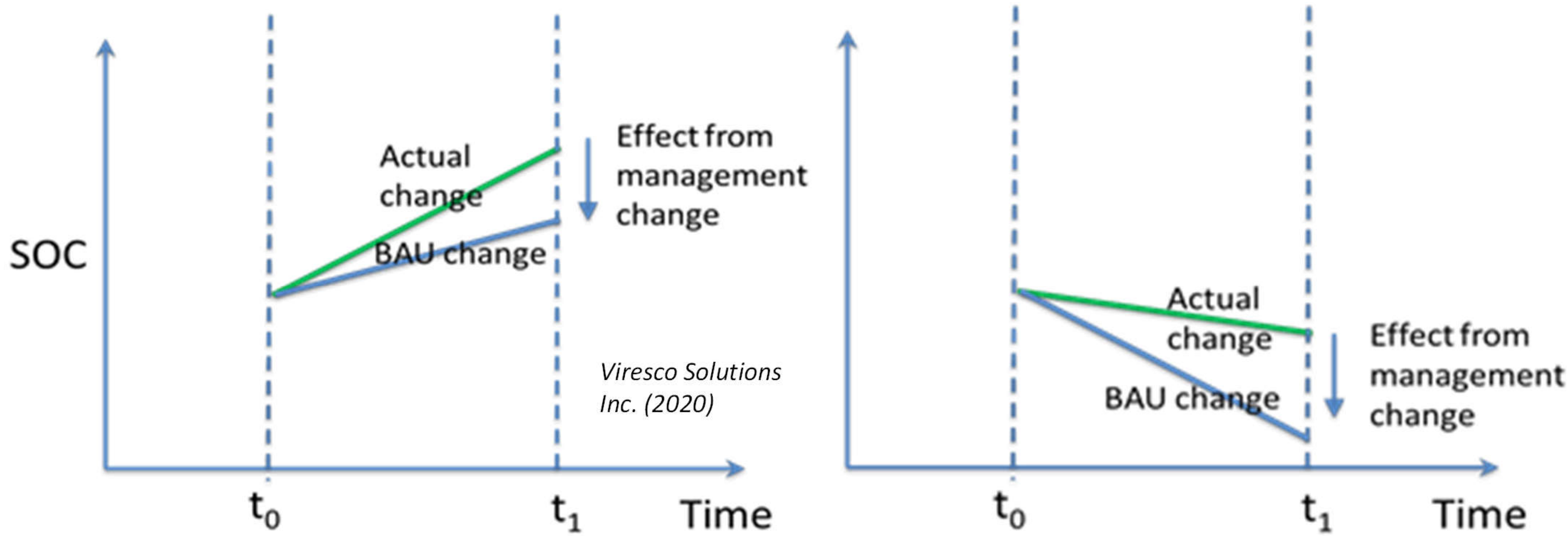
Overall SOC change and effect on atmosphere since t0 – this considers the SOC change from a fixed SOC stock at a point in time at which the management change is implemented. This case does not include changes that would have occurred over time without the management change.

SOC change is limited to the effect of a management change only – this considers a business-as- usual (BAU) baseline where an assumed background rate of SOC change is included in the quantification so that the SOC change is only due to the management change.

Most carbon markets require comparison to a business-as-usual baseline to develop offset credits specifically from the implementation of a management change.

Carbon Stock Change Assessment

It's important to consider what SOC change is to be measured!



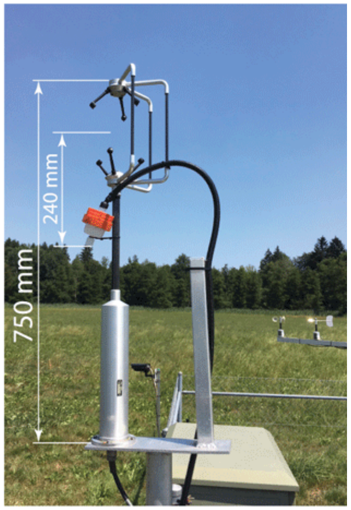
With a BAU baseline, it is possible to have a C credit even if SOC decreases due to changing weather patterns, providing the BAU decreases more. This is called avoided loss (i.e. credit) compared to the loss that would have occurred under the business as usual scenario (i.e. the 'with project' management change loses less than the BAU).

Modeling the BAU SOC allows for project developers to manage this weather-induced risk, which is typically not economically feasible to do with a fixed SOC stock.

Carbon Stocks Assessment Approaches

Main approaches

- Empirical factors
- Measurement only
- Hybrid of modeling and with-project measurement
- Modeling supported by monitoring (measurements)



Measurement approaches

- Direct measurement
- Flux measurements of emissions by flux towers and eddy covariance

Modeling approaches

Extrapolation of empirical models across a larger area

Process soil models: biogeochemical models that exclude simulations of plant growth

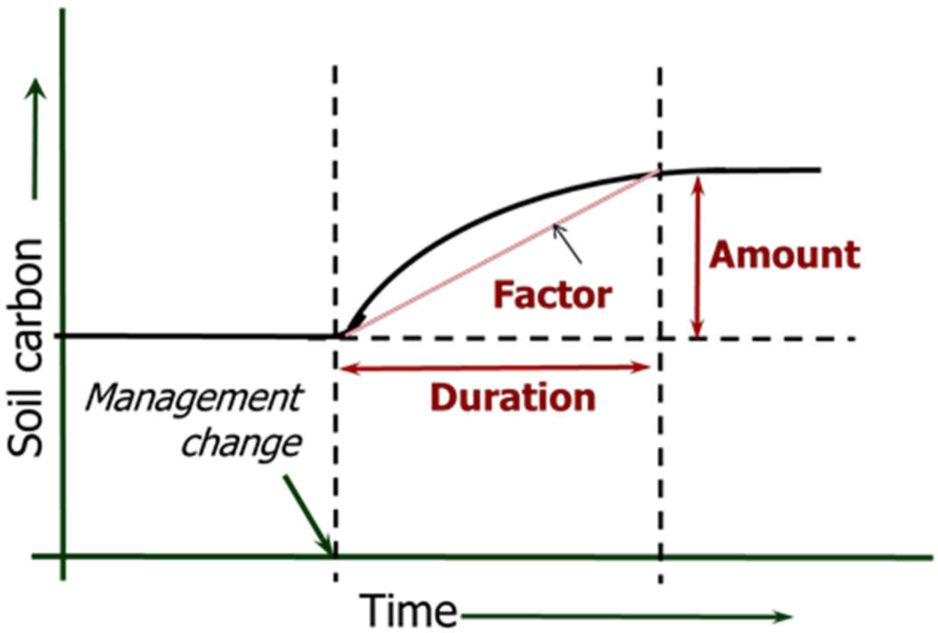
Ecosystem models: biogeochemical models that include simulations of plant growth.

These approaches can be employed independently or in some combination.

It is important to understand the relevance of each quantification approach to the desired use.

Carbon Stocks Assessment Approaches

Empirical Factors



Viresco Solutions Inc. (2020)

Empirical factors are simplified representations or models which can be applied to an appropriate time and area to estimate SOC stock change.

Factors are derived from observations or validated process models for various management practices and locations, depending on the level of detail and rigor required.

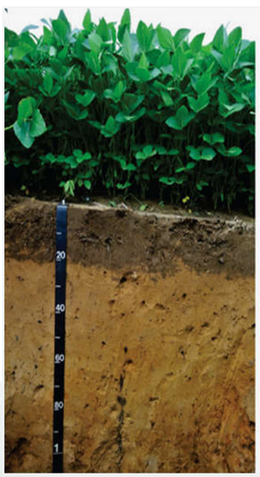
Empirical factors are also simple to implement and understand.

There is often a lack of suitable data from which to derive factors and management changes can be difficult to define given the large variability in land management across diverse landscapes.

Carbon Stocks Assessment Approaches

Measurement only

- Direct measurement of SOC stocks from soil samples to determine SOC change.
- The accuracy and usefulness of empirical measurements is a function of the statistical and scientific design of the sampling approach.
- Rangelands will require expensive sampling due to inherent variability.
- There is no backup when relying solely on direct measurement.
- There is a risk that the SOC change will not be detectable or significant, within a desired commercial timeframe.
- There is no capability to project SOC changes over time when using direct measurement.





Carbon Stocks Assessment Approaches

Hybrid of ‘with-project’ measurement and modeling

- Considers project direct measurement and modeling.
- Rely on project developers to conduct the intensive sampling that is required to generate high quality datasets to validate and true up models
- The BAU SOC change is modeled through well validated models and carbon credits are issued based on modeled estimates of ‘with project’ SOC change.
- Periodic soil carbon measurements (every 5 years) are used to “true-up” modelled results.
- New observations are used to improve the model to better estimate SOC for the with-project scenario and the BAU SOC.
- It’s entirely possible and highly likely that the ‘true-up’ measurements may have so much inherent uncertainty that the true up becomes suspect as well.

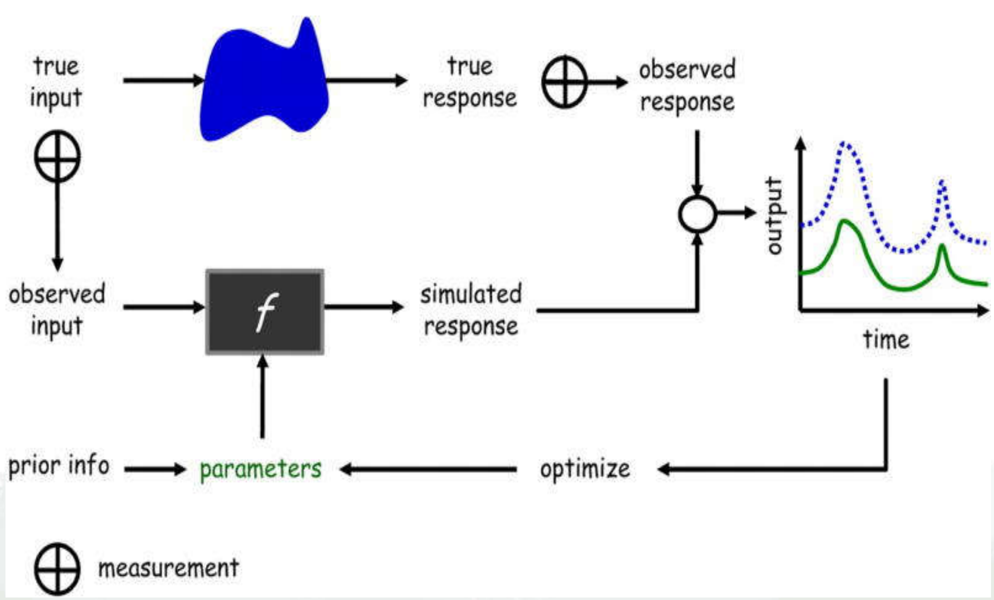




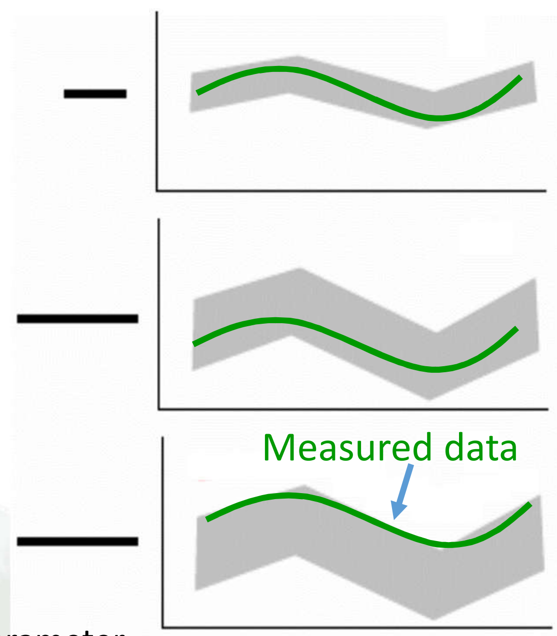
Carbon Stocks Assessment Approaches

Modeling only with measurement support

- Relies on modeling to quantify the SOC change but uses measurement support by way of a well- established network of monitoring sites.
- Proposes establishing a set of key ‘sentinel sites’ across the project domain, generating high-quality validation data from a wide range of combinations of practices, land types, and weather/soil/topographic conditions for which the model will be applied.
- Require some on-going measurements to ensure that the model remains validated.
- The overall cost of this approach will be low, and this will be a versatile approach.
- Carbon credits can be issued annually based on model estimates supported by measurements.



Vrugt *et al.* 2008, Vadose Zone Journal



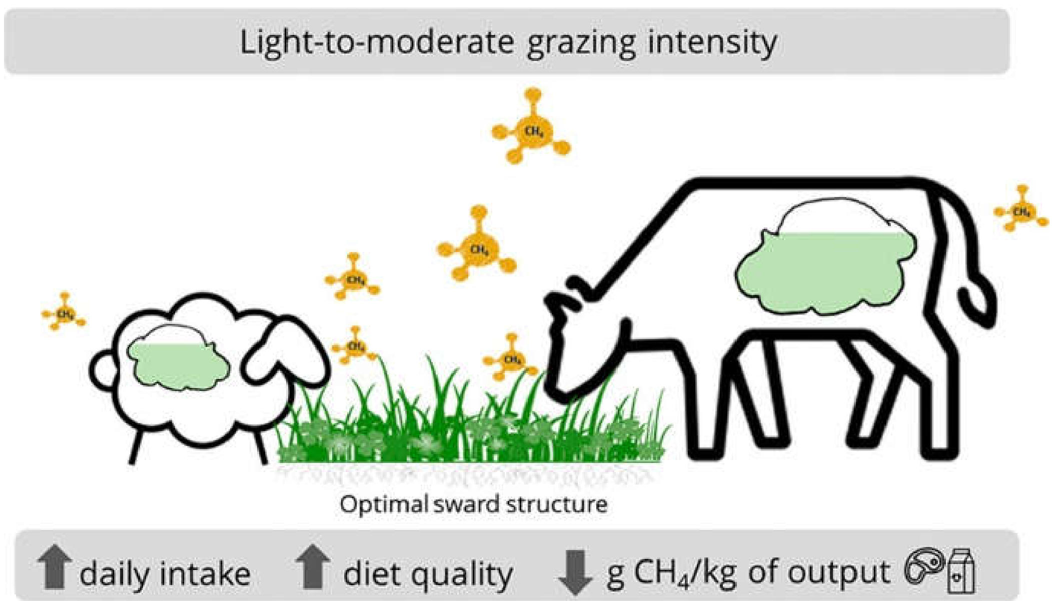
Parameter range

Model outputs

Carbon Sequestration Assessment of Improved Livestock Farming

High grazing intensity shifts pasture vegetation composition towards less desirable plant communities.

Overgrazing limits potential carbon sequestration in pastures and accelerates carbon loss from soil by increasing erosion and deterioration of soil structure.



Sánchez Zubieta et al., 2021, STOTEN 754 (142029)

Optimizing grazing pressure and improving grazing livestock distribution is critical to fully benefit from the carbon sequestration capacity of natural grasslands and traditional livestock herding practices.

Improved grazing management through herd restructuring (more intensive to less intensive grazing pressure) and promoting seasonal pasture rotations can potentially rehabilitate vegetation and soil in degraded pastures in the short-term.

Carbon Sequestration from Herd Restructuring

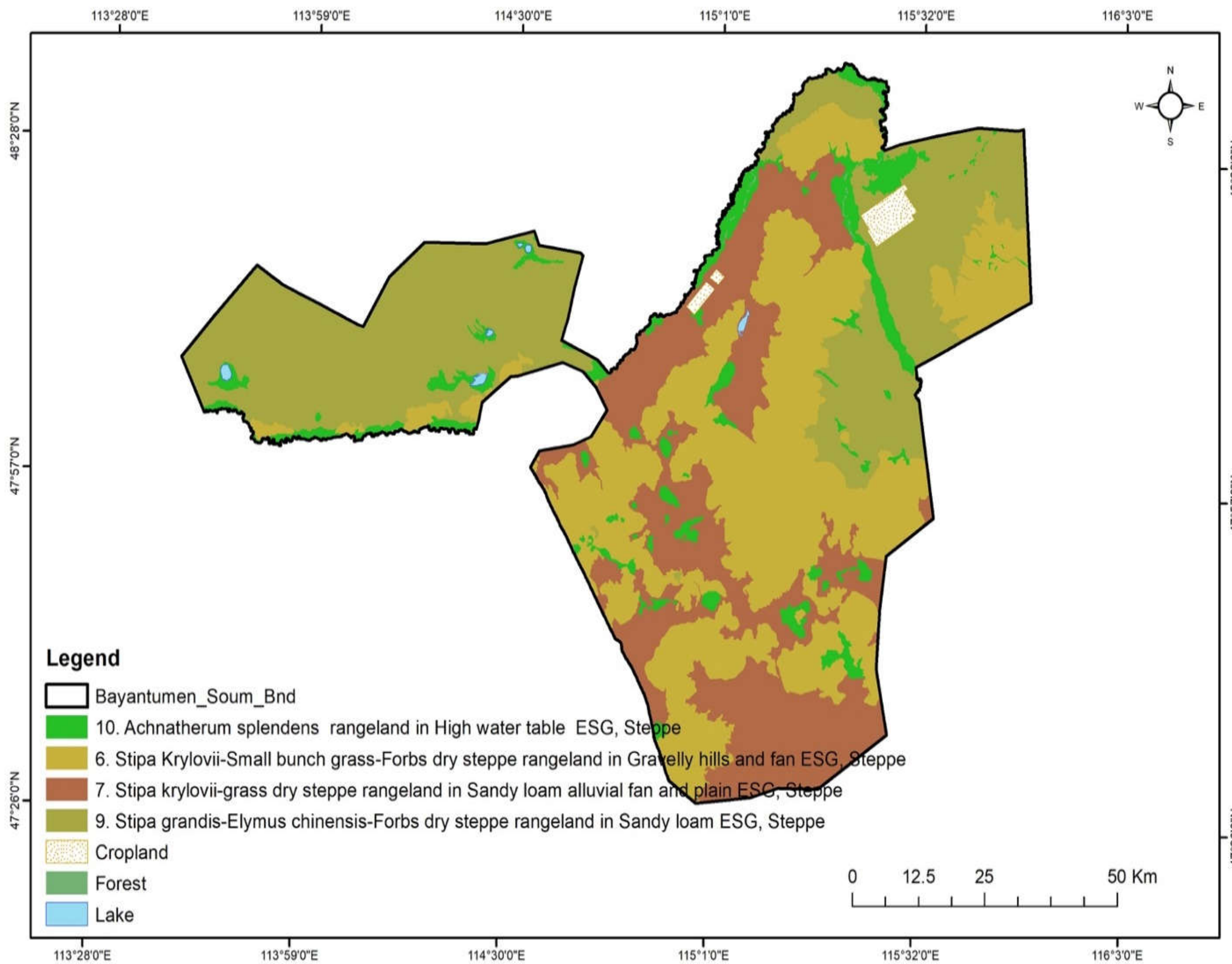
Assuming an average climate and livestock-marketing year , herd restructuring can potentially drop the number of grazing cattle by 20% (333 to 267 SUs) and sheep by 30% (381 to 264 SUs) in the short term (3-5 years).

Cattle types	Current - 20 Adult Cows			
	Total Aug	**Total Dec**	**SUs Aug^**	**SUs Dec^**
Adult cows (42 months and older)	20	17*!	120	102
Calves (born in spring)	19	18*	38	36
Yearlings (16-18 months old)	18	17*	54	51
Steers (30 months old)	8	7*	48	42
Replacement heifers (30 months old)	8	5ā	48	30
Non-pregnant replacement heifers (34 months old)	0	3!	0	21
Steers (42 months old)	8	7*	48	42
Steers (54 months old)	7	0!	42	0
Bull for breeding	1	1	6	6
Open cows (48 months and older)	3	2!	18	12
Total	**92**	**77**	**422**	**333**

Cattle types	With Project - 40 Adult Cows			
	Total Aug	**Total Dec**	**SUs Aug^**	**SUs Dec^**
Adult beef cows (42 months and older)	35	30*!	210	180
Adult milk cows (42 months and older)	5	5	30	30
Calves (born in spring)	40	5£!	80	10
Replacement heifers (18 months old)£	5	5ā	15	15
Replacement heifers (30 months old)ā	5	4*	30	24
Non-pregnant replacement heifers (34 months old)	1	0!	6	0
Bull for breeding	2	2	12	12
Total	**93**	**51**	**383**	**267**

Carbon Sequestration from Herd Restructuring

Map of Ecological Site Groups of Rangelands in Bayantumen Soum.



Mongolian rangelands are divided into around 22 ecological site groups, based on their productivity and capacity to endure different intensities of use, and to recover and regrow after being used.

Based on the vegetation plot data and state and transition models, the majority of vegetation communities within the *soum* area have the potential to recover in the short-term through optimized grazing and pasture management.

Vegetation Carbon Sequestration from Herd Restructuring

Forage yield for different states (health) of key ecological site groups (ESGs) in Bayantumen Soum.

<table>
<tr><th colspan="4">Steppe Zone</th></tr>
<tr><th colspan="4">Stipa krylovii – grass dry steppe rangeland in sandy loam alluvial fan and plan ESG</th></tr>
<tr><td>Reference state</td><td>Grass-thinned state</td><td>Artemisia frigida or Kochia prostata dominate</td><td>Degraded state</td></tr>
<tr><td>890-1000 kg/ha</td><td>550-620 kg/ha</td><td>370-425 kg/ha</td><td>370-425 kg/ha</td></tr>
<tr><td>30-34 SU/100 ha</td><td>30-34 SU/100 ha</td><td>18-21 SU/100 ha</td><td>18-21 SU/100 ha</td></tr>
<tr><th colspan="4">Stipa grandis – Elymus chinensis – forbs dry steppe rangeland in sandy loam alluvial plan and fan ESG</th></tr>
<tr><td>Reference state</td><td>Forb decreased state</td><td>Stipa grandis decreased</td><td>Degraded state</td></tr>
<tr><td>1300-1470 kg/ha</td><td>760-800 kg/ha</td><td>670-710 kg/ha</td><td>350-370 kg/ha</td></tr>
<tr><td>78-86 SU/100 ha</td><td>41-44 SU/100 ha</td><td>34-36 SU/100 ha</td><td>17-18 SUs/100 ha</td></tr>
<tr><th colspan="4">Achnatherum splendens rangeland in high water table ESG</th></tr>
<tr><td>Reference state</td><td colspan="2">Grass decreased state</td><td>Degraded state</td></tr>
<tr><td>380 - 400 kg/ha</td><td colspan="2">150 - 290 kg/ha</td><td>80 -130 kg/ha</td></tr>
<tr><td>22-24 SU/100 ha</td><td colspan="2">8-16 SU/100 ha</td><td>4 -7 SU/100 ha</td></tr>
<tr><th colspan="4">Stipa krylovii-small bunch grass forbs dry steppe rangeland in gravelly hills and fan ESG</th></tr>
<tr><td>Reference state</td><td colspan="2">Grass-thinned state</td><td>Degraded state</td></tr>
<tr><td>970-1030 kg/ha</td><td colspan="2">900-940 kg/ha</td><td>362-679 kg/ha</td></tr>
<tr><td>57-62 SU/100 ha</td><td colspan="2">45-52 SU/100 ha</td><td>18-34 SU/100 ha</td></tr>
</table>

Considering coarse estimates of the current state of vegetation, and rough estimates of the distribution and area proportion of seasonal pastures.

Soil Carbon Sequestration from Herd Restructuring

- Realistic ranges (i.e., min and max) of carbon sequestration rates (tC/ha/yr) from relevant studies for both pasture vegetation and soil, including sequestration rates for different levels of degradation (heavily vs. moderately degraded), grazing pressures (high vs. moderate) and grazing system practices (continues vs. rotational).
- Carbon sequestration ranges for Ecological Site Groups (ESGs) by considering coarse estimates of the current state of vegetation and soil, and rough estimates of the distribution and area proportion of seasonal pastures.

Ecological Site	Area (ha)	C sequestration (t /ha/yr)		C sequestration (t CO2e/ha/yr)		C sequestration (t /yr)		C sequestration (t CO2e/yr)	
		Min	Max	Min	Max	Min	Max	Min	Max
6. Stipa Krylovii-Small bunch grass-Forbs dry steppe rangeland in Gravelly hills and fan ESG, Steppe	301,950	0.15	0.34	0.55	1.47	45,293	102,663	166,073	442,860
9. Stipa grandis-Elymus chinensis-Forbs dry steppe rangeland in Sandy loam ESG, Steppe	275,727	0.05	0.15	0.18	0.55	13,786	41,359	50,550	151,650
7. Stipa krylovii-grass dry steppe rangeland in Sandy loam alluvial fan and plain ESG, Steppe	192,157	0.1	0.25	0.37	0.92	19,216	48,039	70,458	176,144
10. Achnatherum splendens rangeland in High water table ESG, Steppe	55,779	0.15	0.3	0.55	1.25	8,367	16,734	30,678	69,538
Total	**835,680**					**86,661**	**208,795**	**317,758**	**840,192**

Carbon Sequestration from Herd Restructuring

- Annual sequestration estimate of 99.8 to 224.3 thousand tons of carbon or 366.1 to 897.1 thousand tons of CO_2e from pasture vegetation and soil (86.8% to 93% in the soil).
- Annual sequestration rate of 0.12 to 0.27 tons carbon per hectare per year or 0.44 to 1.07 tons CO_2e per hectare per year.
- Equal to removal of direct GHG emission from 202 to 495 thousand cattle heads or 1,570 to 3800 thousand sheep heads annually.
- Equal to CO_2e removal by 18.3 to 44.8 thousand typical young trees annually (based on a conservative annual carbon removal of 20 kg).

Ecological Site (ESGs)	Area (10^3 ha)	Vegetation C Sequestration				Soil C Sequestration			
		Total C (10^3t/yr)**		Total CO_2e (10^3t/yr)!		Total C (10^3t/yr)		Total CO_2e (10^3t/yr)	
		Min	Max	Min	Max	Min	Max	Min	Max
6. *Stipa Krylovii*-Small bunch grass-Forbs dry steppe rangeland	302.0	5.7	6.8	20.9	24.8	45.3	102.7	166.1	442.9
9. *Stipa grandis-Elymus chinensis*-Forbs dry steppe rangeland	275.7	4.3	5.1	15.9	18.8	13.8	41.4	50.5	151.6
7. *Stipa krylovii*-grass dry steppe rangeland	192.2	2.8	3.3	10.3	11.9	19.2	48.0	70.5	176.1
10. *Achnatherum splendens* rangeland	55.8	0.3	0.4	1.2	1.4	8.4	16.7	30.7	69.5
Total	835.7	13.2	15.5	48.3	56.9	86.7	208.8	317.8	840.2

** Carbon sequestration rates across ESGs ranged from 0.006 to 0.022 and 0.05 to 0.34 tC/ha/yr for vegetation and soil, respectively.

! A conversion factor of 44/12 or 3.67 was used to calculate the CO2e of the carbon sequestration estimates.

Preferred Carbon Stocks Assessment Approach for Mongolia

- SOC stocks can be measured directly, but it can take many years to detect a discernable change in SOC stocks due to significant variability in measurements, management, and weather.
- As an alternative, SOC stocks and their changes can be estimated with process models of SOC – but it is essential that those models are validated with high-quality empirical data.
- The preferred approach is to utilize process models supported by measurements from a monitoring network of sites across the country collecting high-quality data, a Grassland Carbon Observation Network.
- The establishment of this network is the critical and fundamental initial goal on the roadmap towards better, more practical quantification of SOC stocks and their changes.
- The network will collect, manage, and share datasets of observed SOC change paired with information on management practices, soils, climates, and grasslands across the nation to validate and calibrate models.
- The network will leverage all the value possible from relevant past studies of grasslands but, importantly, it will also include new ongoing observations to provide the data to evaluate models for current grassland management and conditions.

Swainson's Hawk
(*Buteo swainsoni*)

Picture: ABMI NatureLynx

Questions and feedback

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It’s Our Nature *to Know*

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