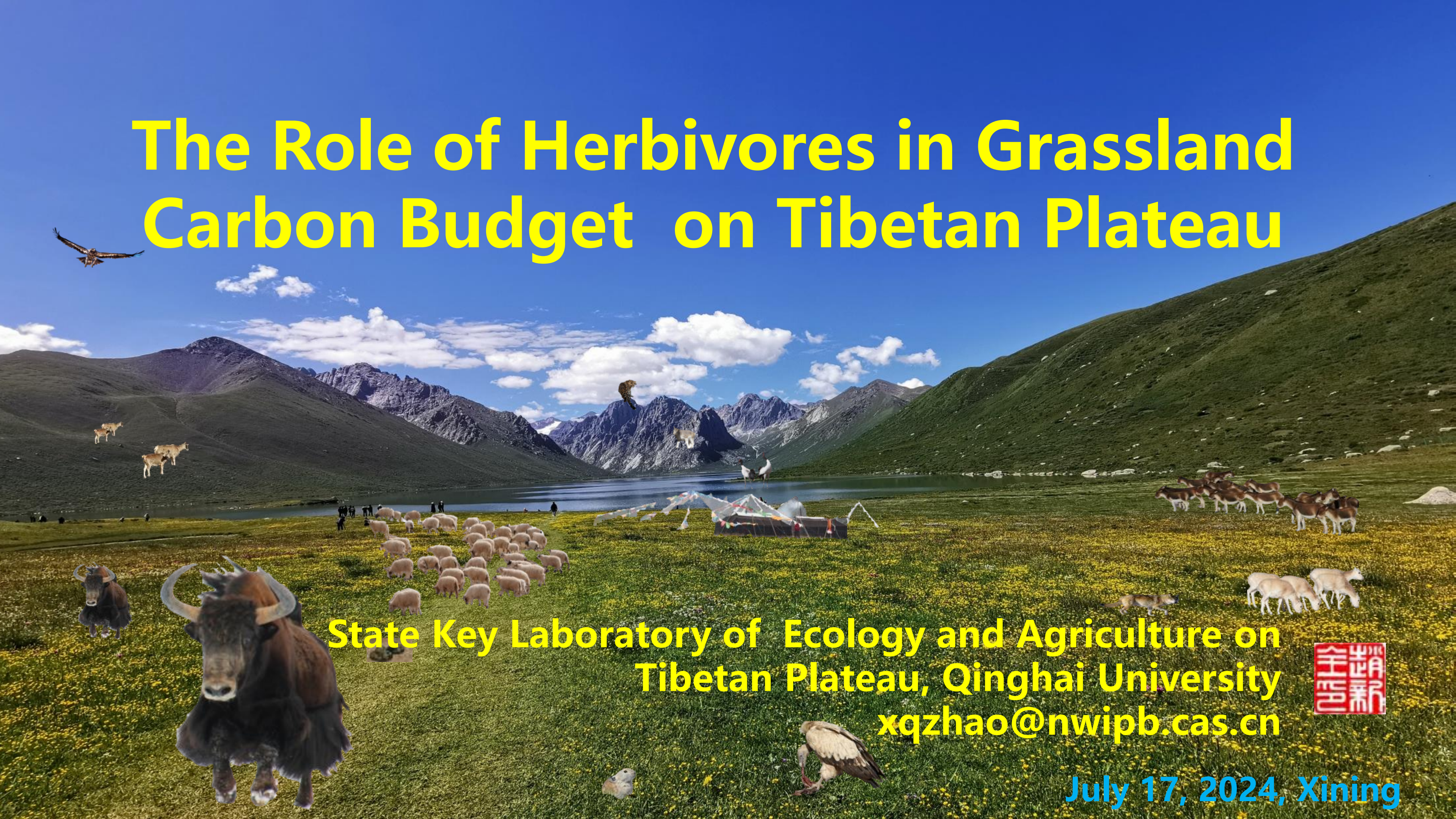

The Role of Herbivores in Grassland Carbon Budget on Tibetan Plateau

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July 17, 2024, Xining

三江源国家公园
THREE-RIVER-SOURCE NATIONAL PARK

Outline

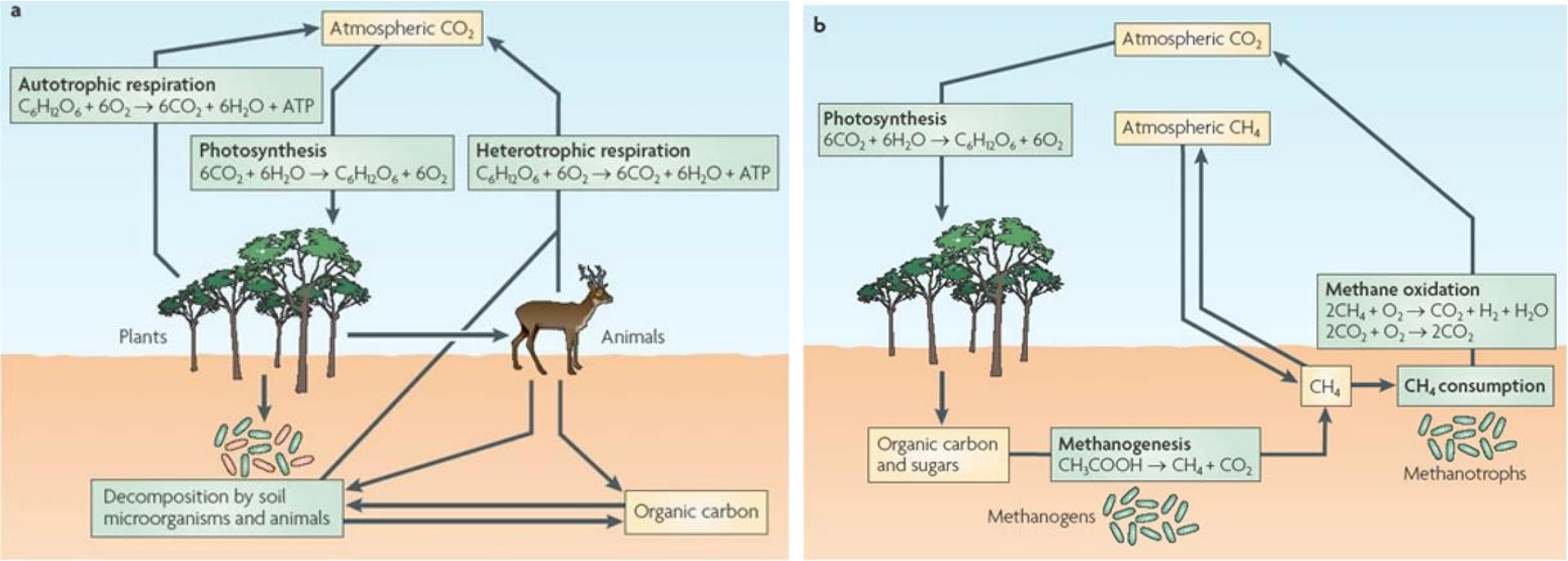
1. Background and Concepts

2. The role and contribution of herbivores

3. Carbon budget based on the utilization of herbivores

1 Background and Concepts

□ The concept of carbon neutrality and the principle of ecosystem carbon source and sink

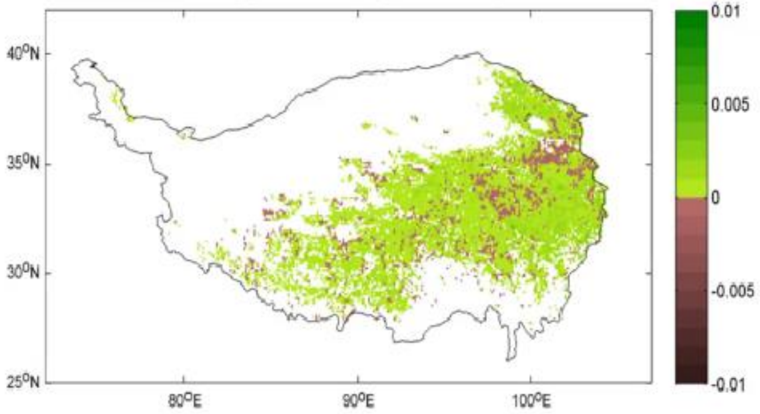


Carbon neutrality=carbon emissions - (land sea carbon sink+CCUS)=0, carbon emissions=fossil fuels+land use, CUCC refers to the capture, storage, and utilization of carbon dioxide using physical, chemical, and biological methods

1 Background and Concepts

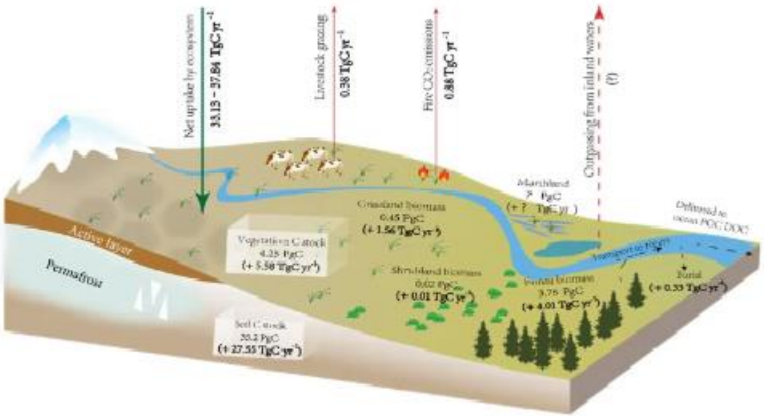
Overall Plateau Vegetation turned green and Carbon Sink Function enhanced

Vegetation greening on the Qinghai–Tibet Plateau is particularly striking



Based on ground monitoring and a variety of remote sensing indices, it is confirmed that the global vegetation has been greening continuously since the 1980s, and the trend is particularly striking on the Qinghai–Tibet Plateau.

Carbon Sink Function of Qinghai–Tibet Plateau ecosystem

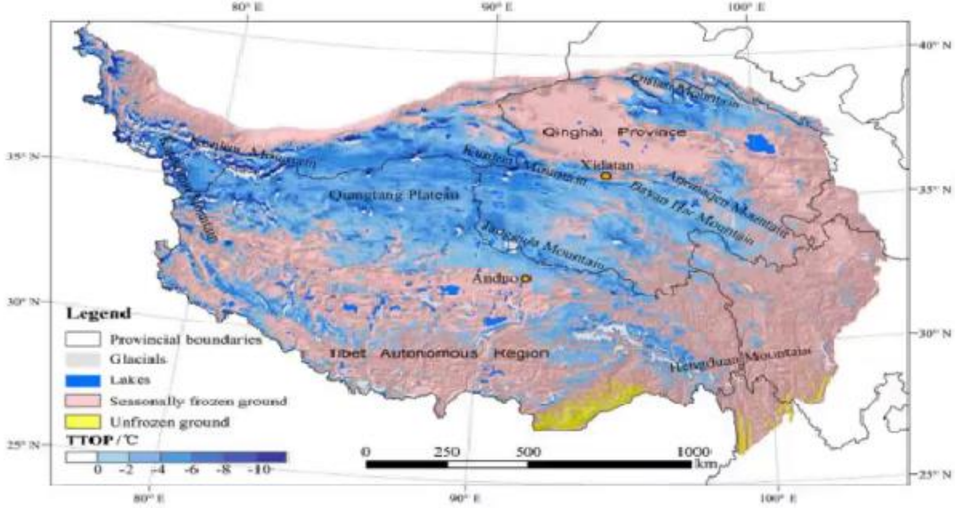


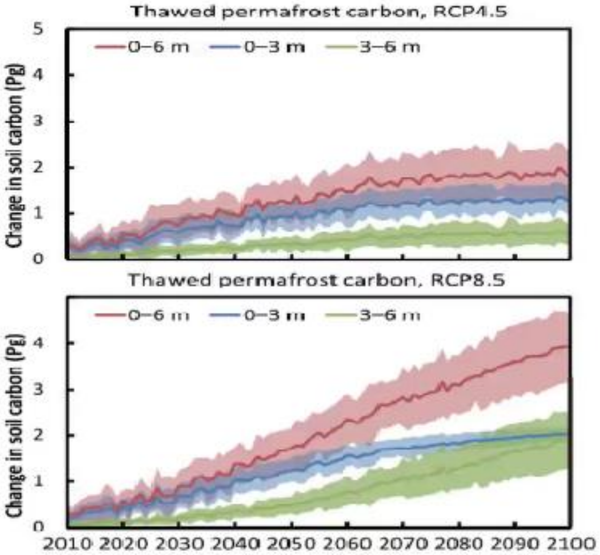
The carbon sink function of Tibetan Plateau ecosystem is significant, and the size is 130 million tons of carbon dioxide per year approximately, accounting for 13% （10%–16%）of China's carbon sink.

Piao et al., 2019, NREE; Piao et al., 2022,中国科学:地球科学; Ding et al., 2022, Science Bulletin

1 Background and Concepts

Carbon emissions of deep frozen soil will become a great threat to plateau carbon sinks in the future





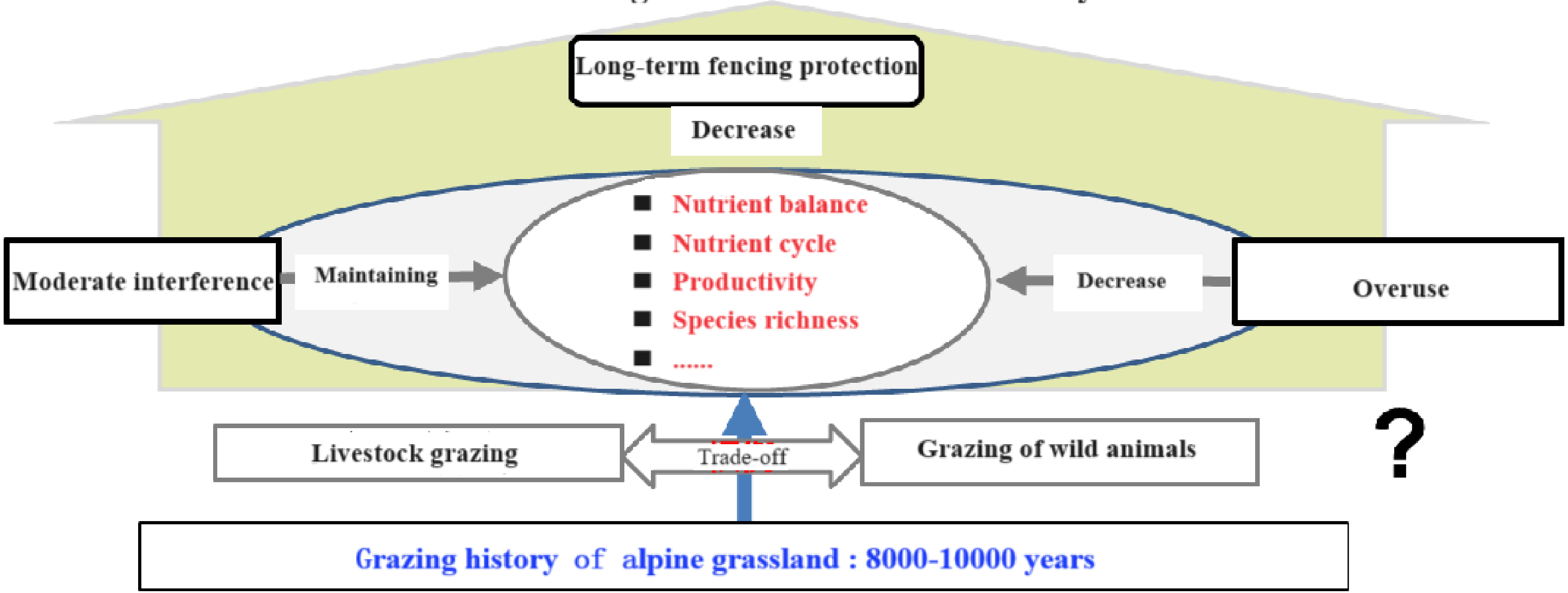
Permafrost covers more than 40% of the total area of the plateau, and the soil carbon storage is about 37 billion tons of carbon, about half of which is stored in permafrost. However, about 22-45% of soil organic carbon stored in the permafrost will melt, and the deep organic carbon melting below 3 meters accounts for as much as 30-46%.

Ding et al., 2019, Nature Communications; Wang et al., 2020, Science Advances

1 Background and Concepts

□ Grazingtic Disclimax , Zootic Disclimax or Climatic Climax ?

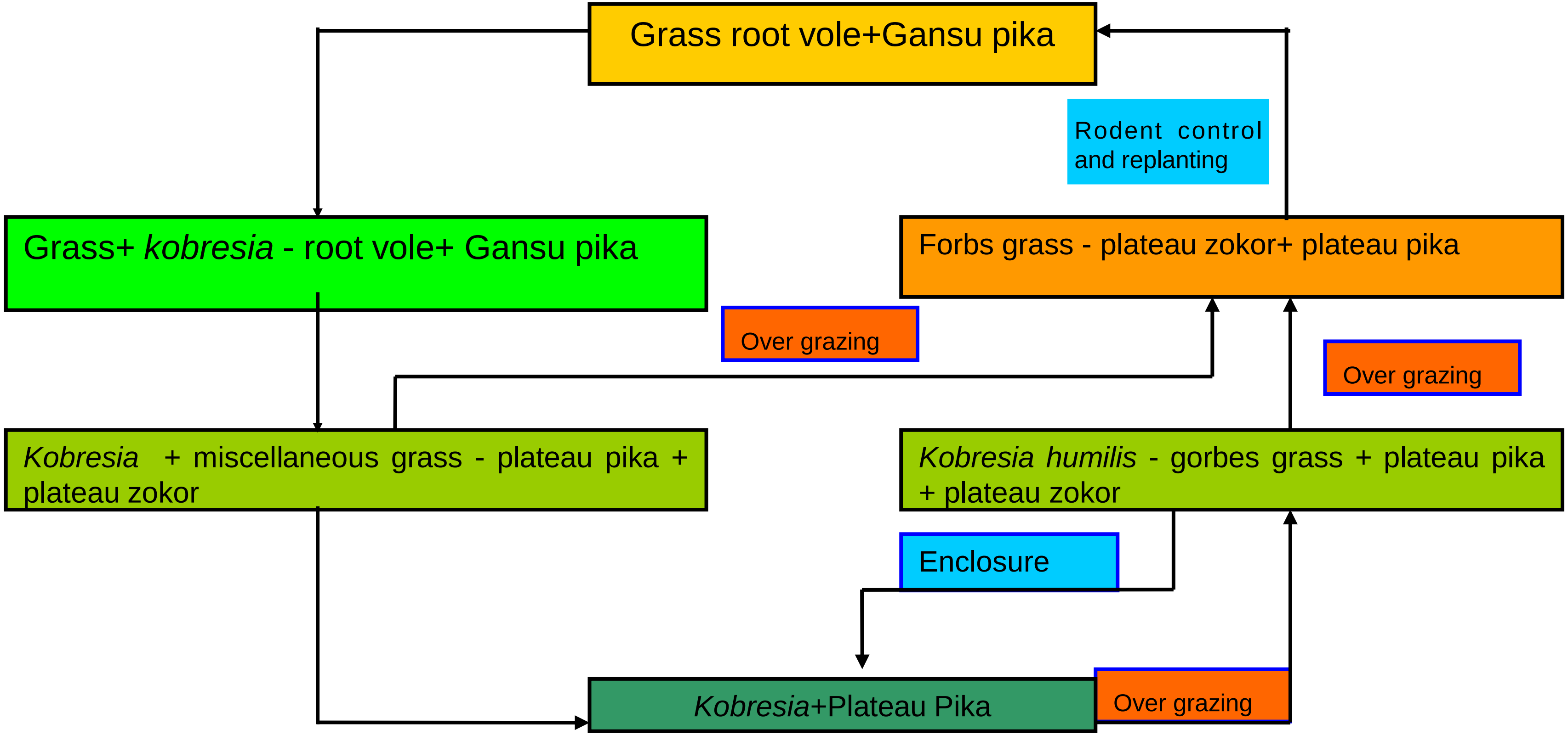
Alpine grassland is a deviated climax community formed under suitable intensity utilization, and the management of herbivores is the key



Guo., Zhao., Liu. et al., *BMC Evolutionary Biology.* 2006, 6:73.

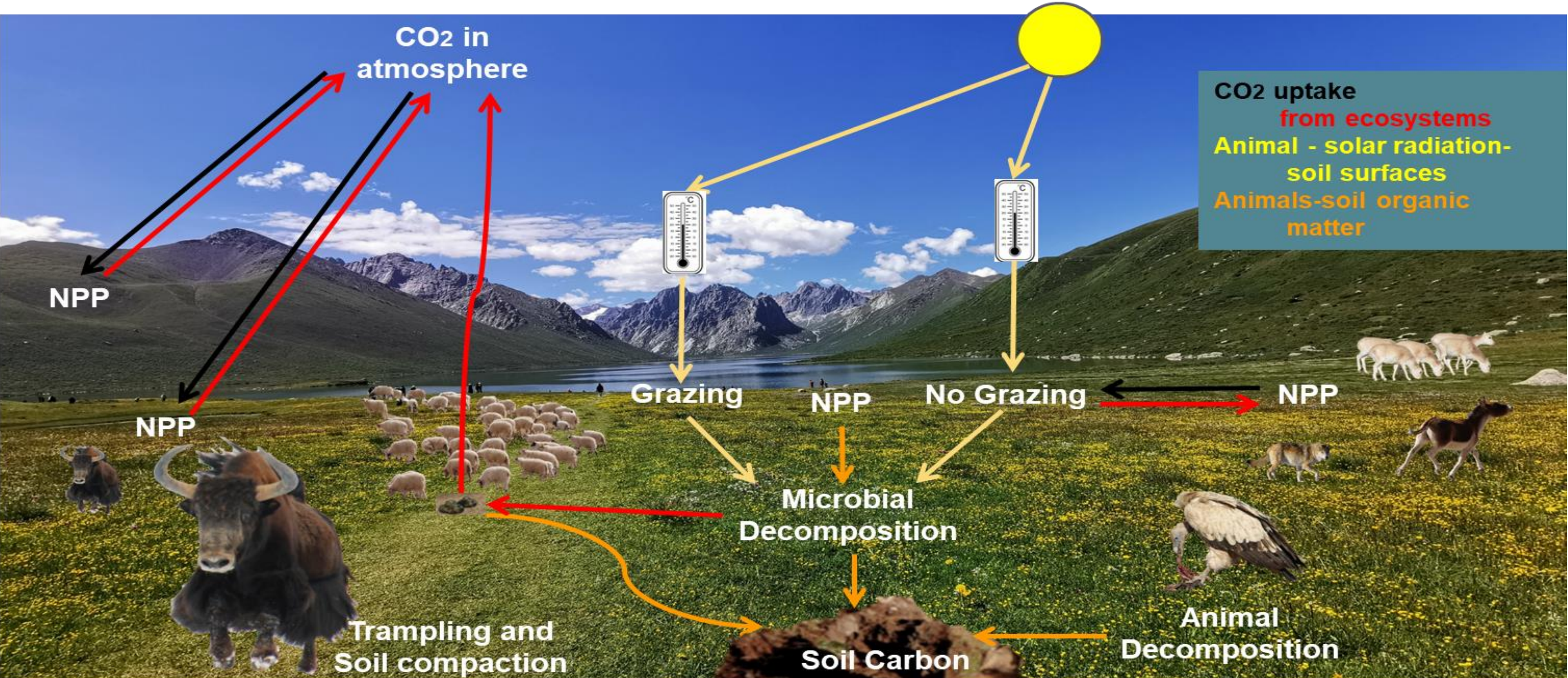
1 Background and Concepts

The process of grazing deviation and succession



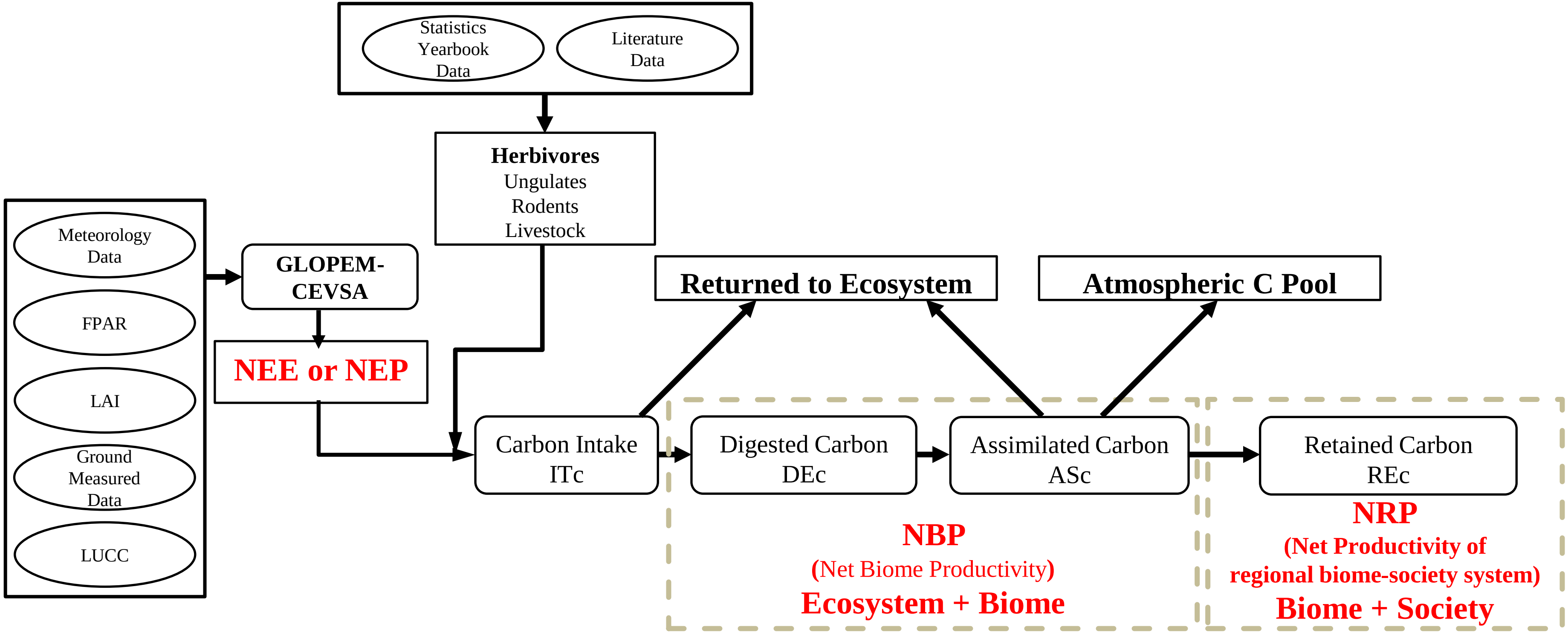
1 Background and Concepts

- Herbivorous determine the size of grassland carbon sinks, and the goal of carbon sink management is to reasonably graze and succession Climax communities



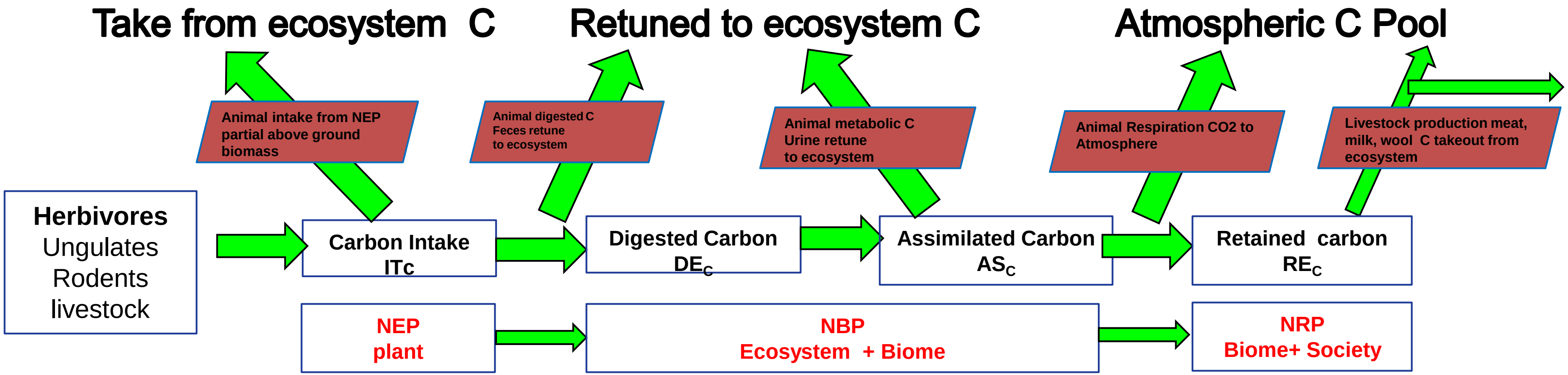
1 Background and Concepts

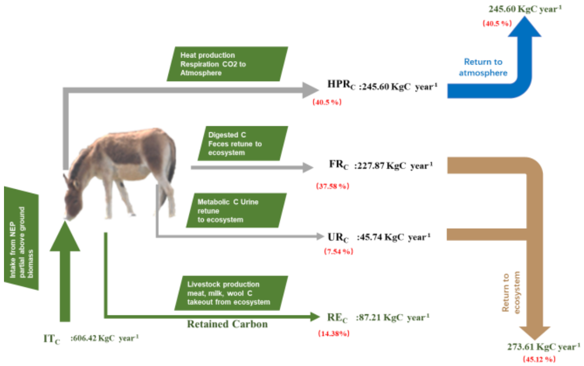
- Is NEP (NEE) a net carbon sink in ecosystems?

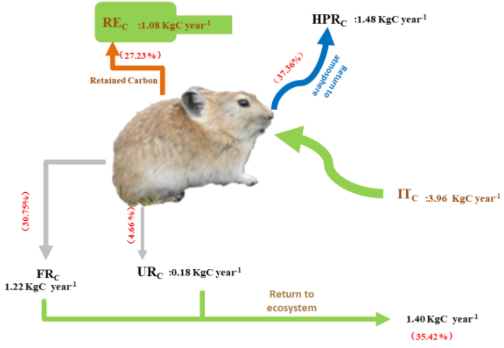


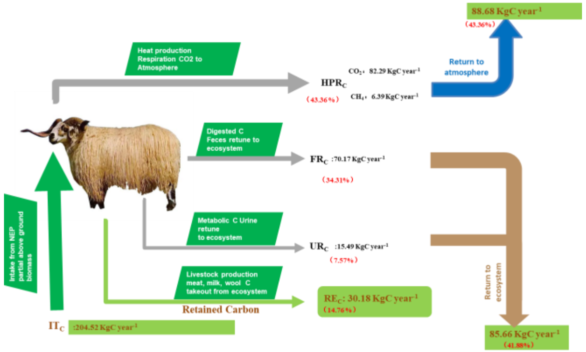
2 The role and contribution of herbivores

Grassland carbon source sink function and control







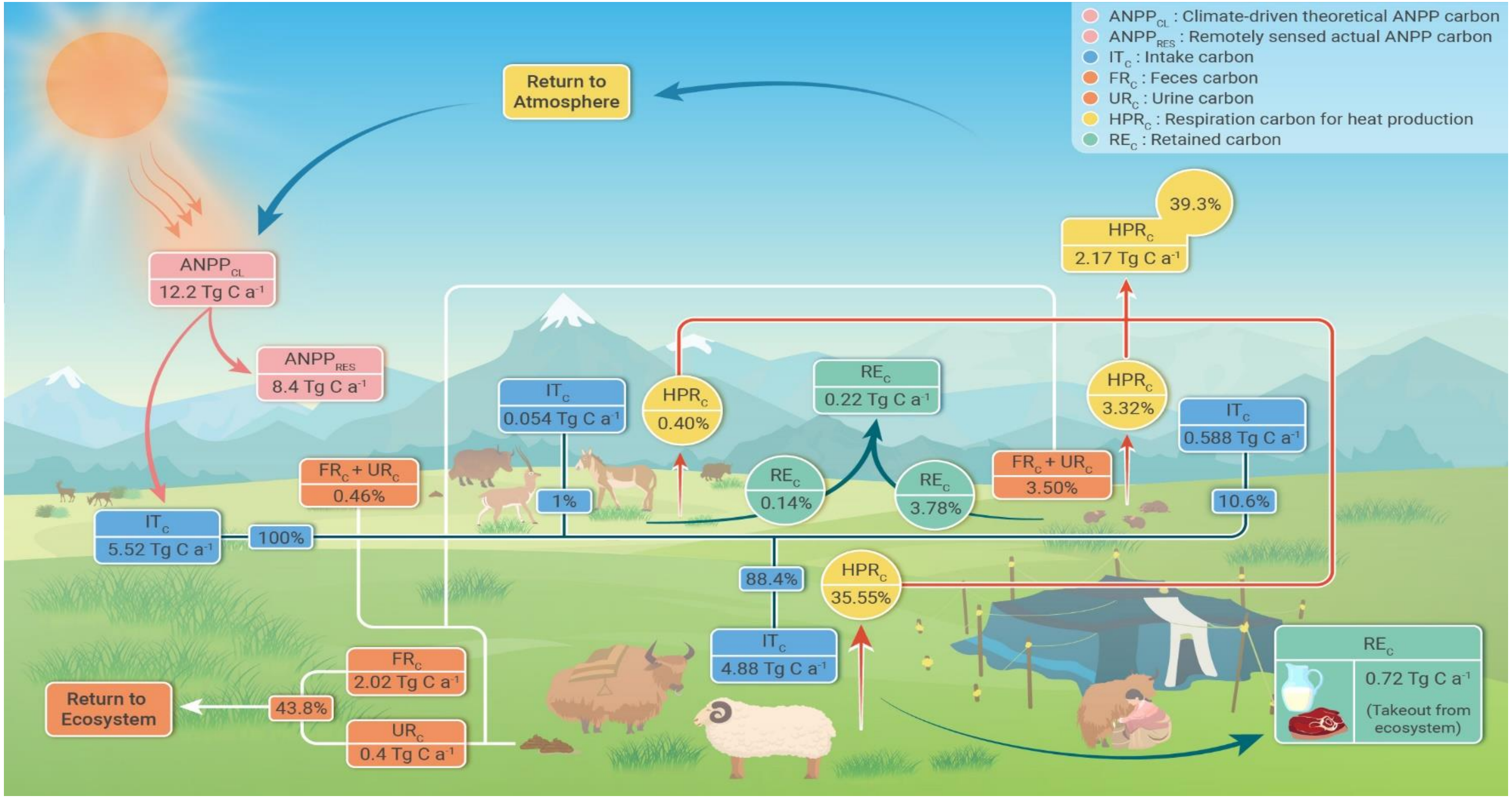


2 The role and contribution of herbivores

■ Carbon balance status of herbivores in the Three Rivers Source Area

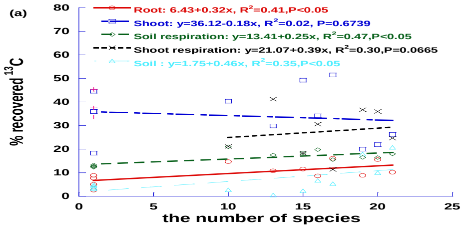
ANPP 12.20Tg

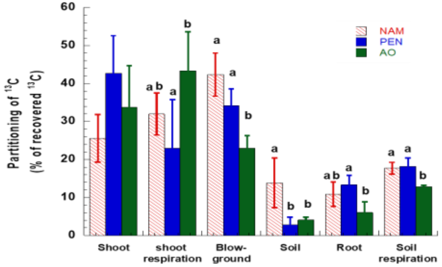
ITc 5,52Tg
FRc 2.02Tg
URc 0.40Tg
HPRc 2.17Tg
REc1 0.72Tg
REc2 0.22Tg

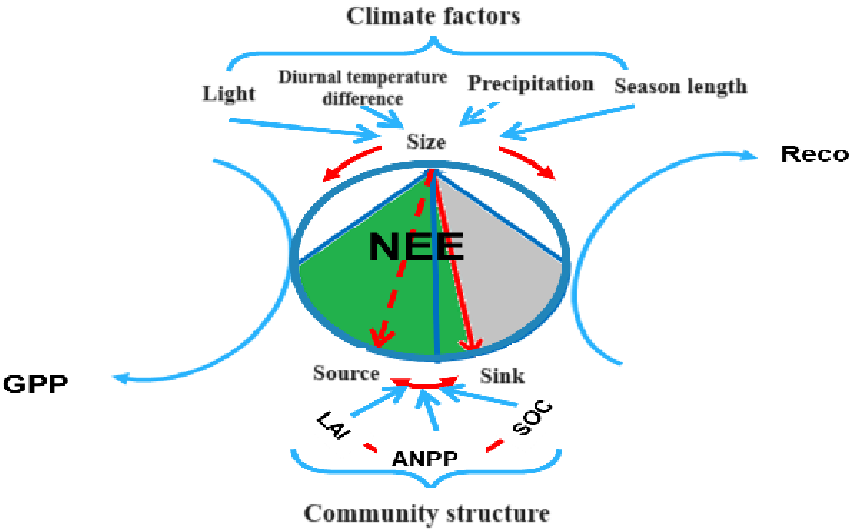


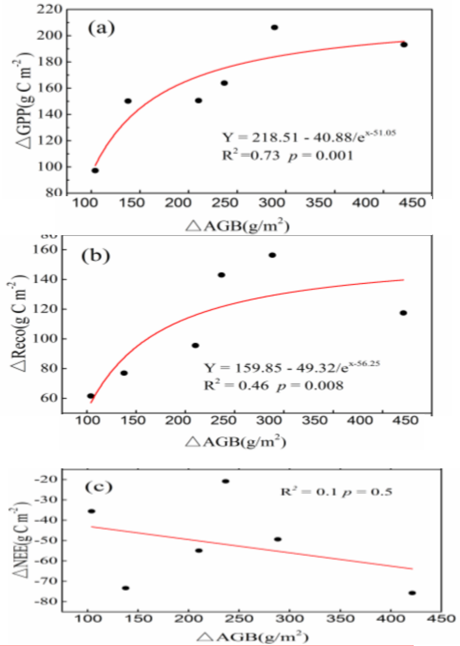
2 The role and contribution of herbivores

□ Carbon source sink function and control









The carbon source/sink function of grasslands on the Qinghai Tibet Plateau is controlled by their community structure, while light and precipitation mainly drive changes in NEE size.

赵亮等，2014，第四纪研究

2 The role and contribution of herbivores

☐ Reasons for Carbon Loss in Alpine Meadows

Plant functional group	Species diversity		Biomass (g m^{-2})		Vegetation cover (%)	
	Fenced	Grazed	Fenced	Grazed	Fenced	Grazed
Grasses	6	6	264.43 (±28.11)	198.30 (±39.60)*	109.5 (±5.07)	81.5 (±9.88)*
Sedges	3	3	29.17 (±11.46)	46.18 (±16.08)	8.5 (±3.70)	17.25 (±12.66)
Legumes	2	5	1.57 (±1.71)	42.58 (±14.79)*	6.5 (±4.43)	41.5 (±11.45)*
Forbs	18	22	56.59 (±25.12)	116.29 (±19.17)*	61.5 (±19.82)	97.25 (±7.50)*
Total	29	36	351.76 (±5.84)	403.35 (±41.29)*	186 (±22.99)	237.5 (±16.82)*
Litter			219.00 (±82.57)	104.08 (±5.39)*		

Table 2 Above- and below-ground C stocks (Mg C ha^{-1}) of the grazed and ungrazed grassland

	Depth (cm)	Grazed	Ungrazed
Shoot		2.35 ± 0.15	7.28 ± 0.05**
Dead roots	0–5	1.61 ± 0.11	1.17 ± 0.27
Living roots	0–5	1.01 ± 0.01	0.30 ± 0.01**
	5–15	0.33 ± 0.01	0.15 ± 0.01**
	15–30	0.54 ± 0.01	0.31 ± 0.02**
Soil	0–5	26.1 ± 1.30	20.5 ± 1.40**
	5–15	41.8 ± 1.70	29.1 ± 3.60**
	15–30	33.8 ± 1.52	34.5 ± 0.66
Total below-ground C stocks	0–30	103.6 ± 4.04	84.9 ± 3.35**

**Indicates highly significant differences at $P < 0.01$ between the grazed and ungrazed plots.

Long term enclosure has changed plant biomass and community structure

2 The role and contribution of herbivores

☐ Reasons for Carbon Loss in Alpine Meadows

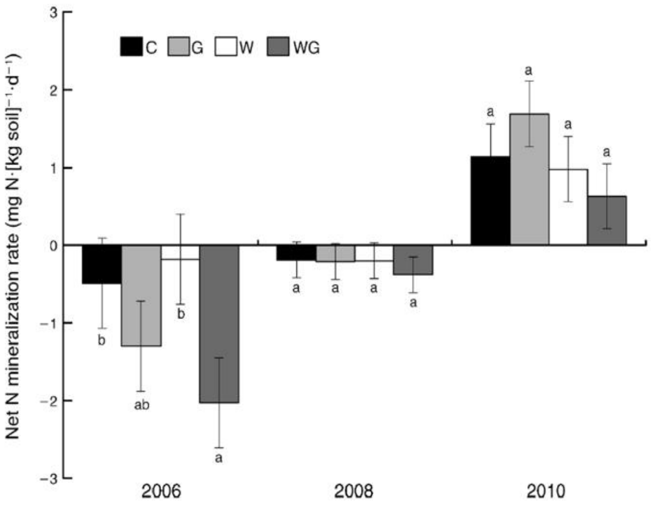
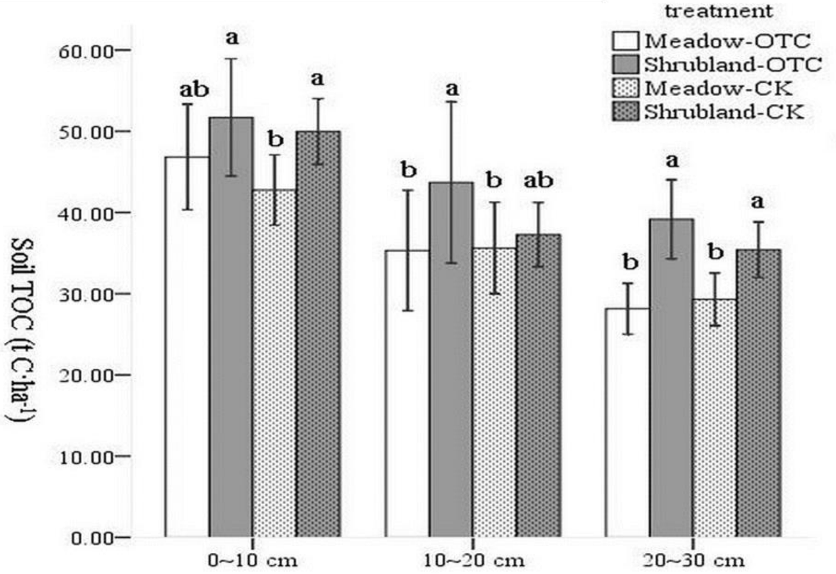


FIG. 1. Net nitrogen mineralization rates at 10 cm soil depth under different treatments. Bars show ±SE. Abbreviations are: C, no warming with no grazing; G, no warming with grazing; W, warming with no grazing; and WG, warming with grazing. Bars with different letters are significantly different ($P \leq 0.05$).

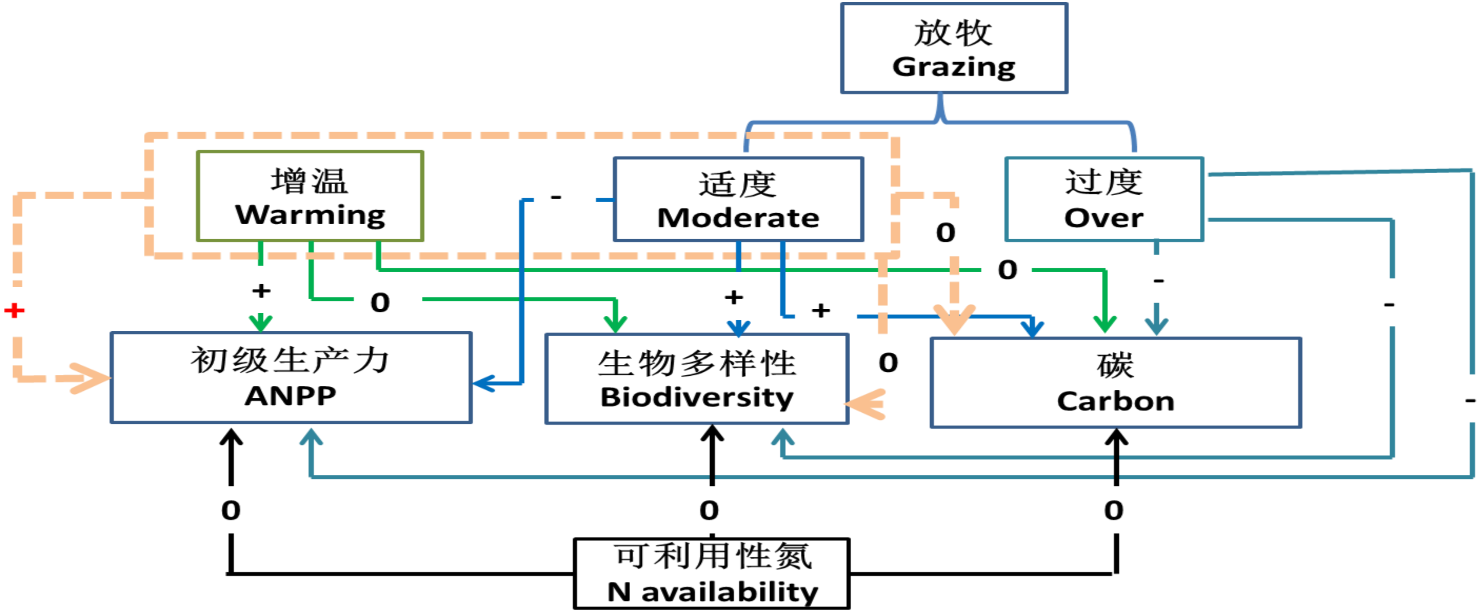


Under moderate grazing conditions, experimental warming did not affect soil nutrition and ANPP

Long term warming does not change the total carbon content in the soil

2 The role and contribution of herbivores

Reasons for Carbon Loss in Alpine Meadows



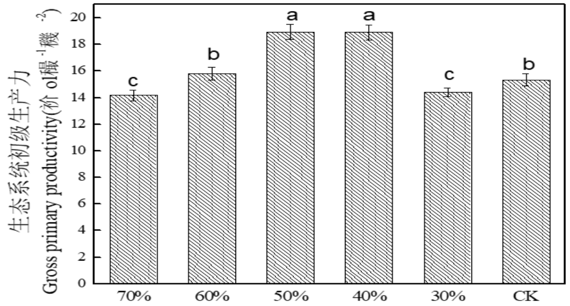
Warming+moderate grazing will not cause carbon loss in alpine meadows. Overgrazing is the main factor causing carbon loss in alpine meadows, and moderate grazing is the "regulator" to address climate change.

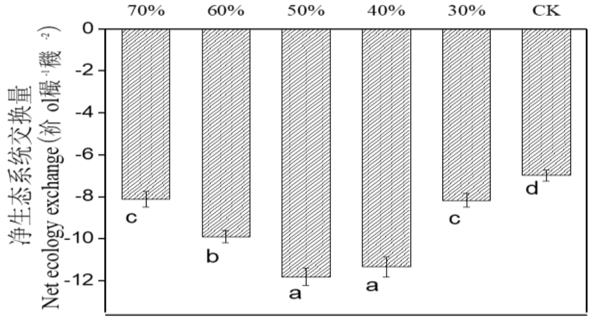
2 The role and contribution of herbivores

Reasons for Carbon Loss in Alpine Meadows

Table 3. Changes (Mean ± standard error) in soil nutrients at different soil layers under stocking rates in the warm-season pasture. (Control (no grazing) CK, Light grazing L, Moderate grazing M, Heavy grazing H, Native grazing N).

Soil nutrient	The depth of soil strata (cm)			
	Grazing intensity	**0–5 cm**	**5–10 cm**	**10–20 cm**
Organic matter (g kg^{-1})	CK	156.81±49.72^{Aa}	97.73±30.07^{a}	72.92±25.03^{a}
	L	130.73±32.74^{a}	90.93±21.98^{b}	59.82±8.73^{b}
	M	118.97±30.15^{b}	85.34±22.23^{b}	55.15±21.13^{b}
	H	103.43±39.05^{b}	78.12±26.33^{b}	45.83±21.24^{b}
	N	93.44±39.03^{Bb}	69.19±22.3^{b}	35.82±11.27^{b}
Organic carbon (g kg^{-1})	CK	90.63±28.82^{Aa}	56.24±9.93^{a}	42.31±9.82^{a}
	L	75.82±18.93^{b}	52.72±12.82^{a}	34.51±5.12^{b}
	M	68.92±17.52^{b}	49.51±1.12^{a}	31.93±9.95^{b}
	H	59.91±22.62^{b}	45.32±15.21^{b}	26.62±9.15^{c}
	N	53.91±20.67^{Bb}	35.31±11.41^{b}	21.62±4.11^{c}



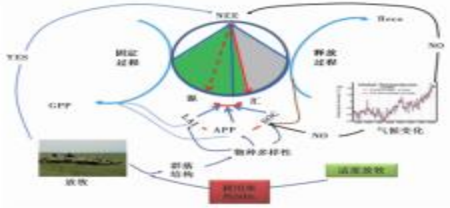


Overgrazing significantly reduces soil carbon storage in alpine meadows, while moderate grazing has a higher NEE

2 The role and contribution of herbivores

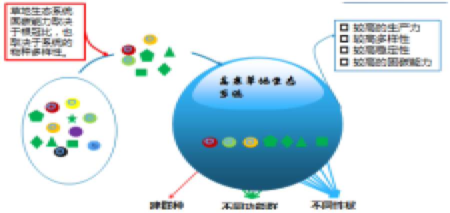
The principle of maintaining and increasing carbon sink in alpine meadows

Reasonable utilization of natural grasslands



Moderate grazing, following the grazing principle of "taking half and leaving half"

Restoration of degraded natural grasslands



Adhere to the principles of "increasing original species" and "classified governance"

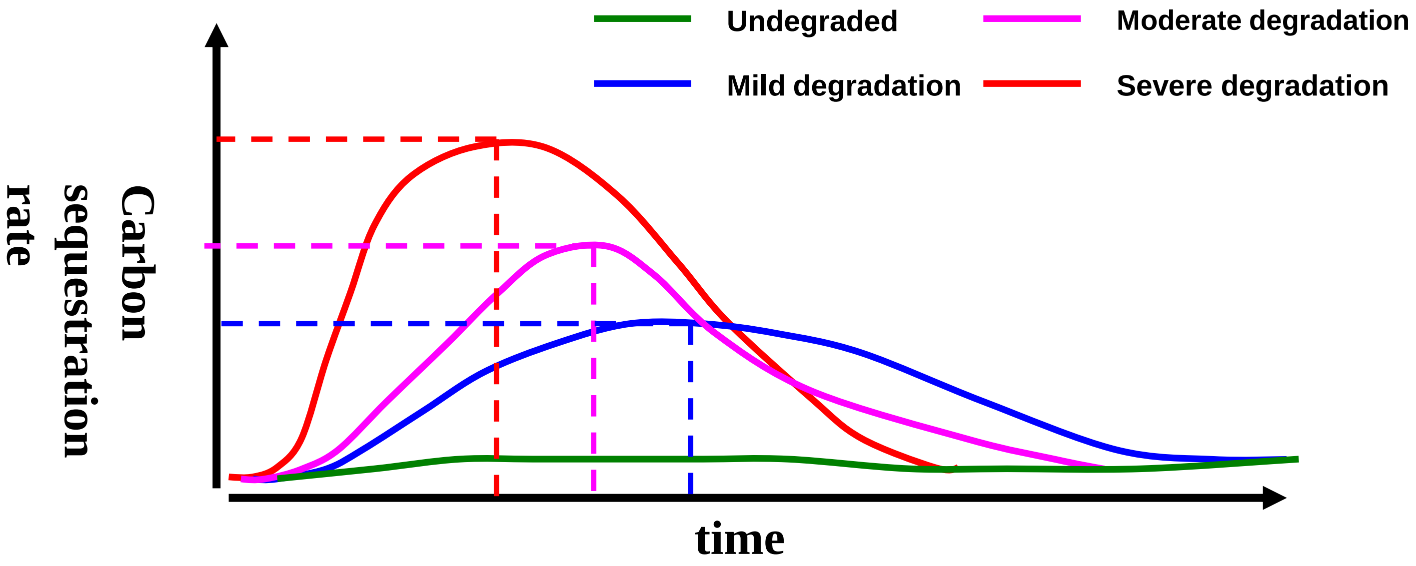
Transformation of grassland production mode

Grassing and animal husbandry, segmented breeding.

Maintain a rich community structure and optimize traditional regional business models

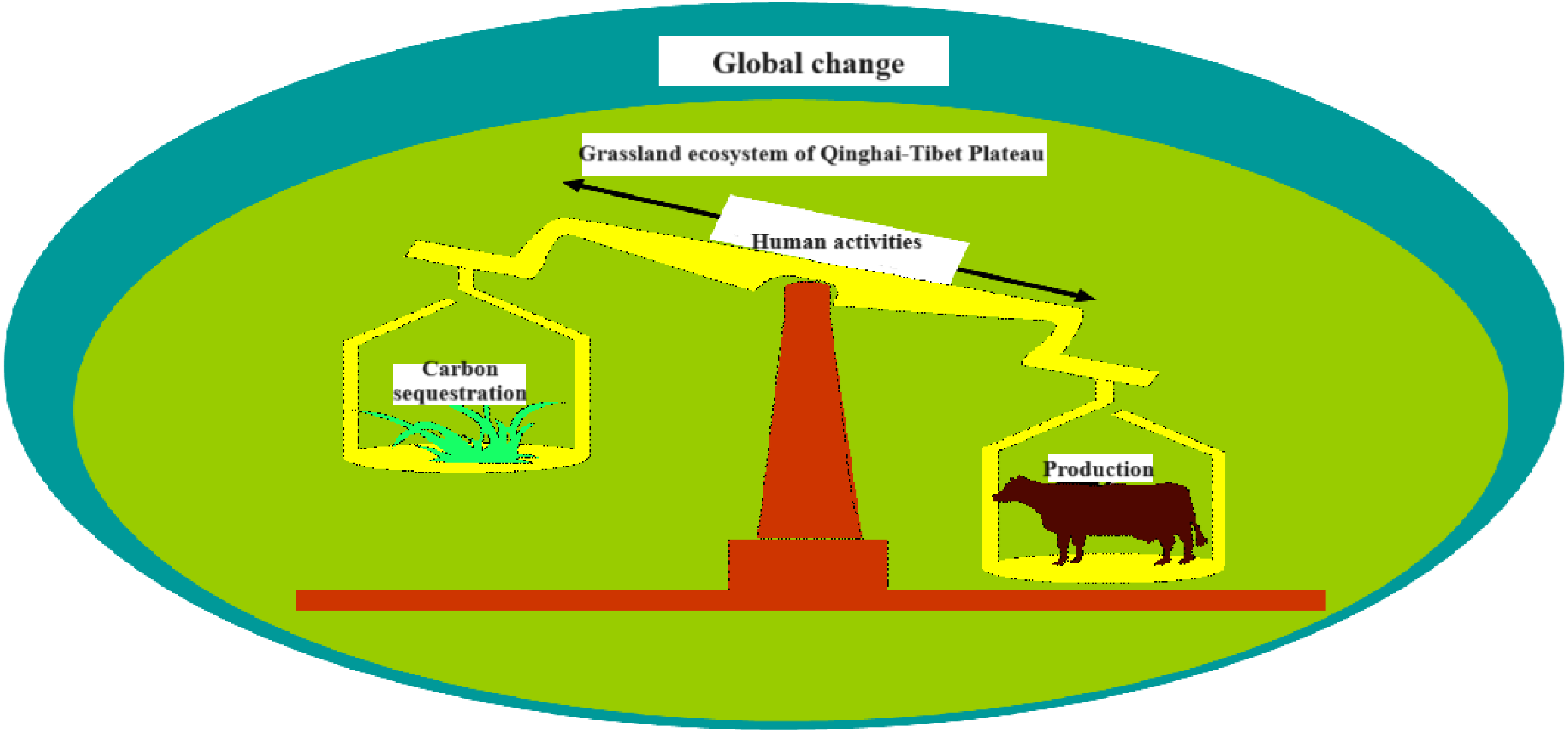
2 The role and contribution of herbivores

□ Changes in carbon sequestration rate at different stages of degradation succession



The initial carbon content of soil in ecosystems and the changes in soil carbon input caused by management methods will significantly affect the carbon balance point and carbon sequestration rate of soil in ecosystems.

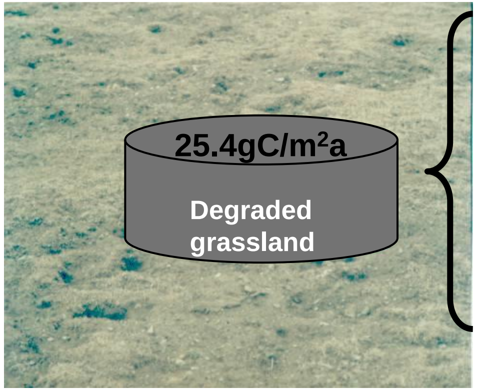
3 Carbon budgets based on the utilization of herbivores



Coordination of production carbon sequestration functions in alpine grasslands under the context of global change

3 Carbon budgets based on the utilization of herbivores

Regenerated degraded grasslands and restore carbon sink functions



Enclosure

Low cost
Long time
Relatively stable

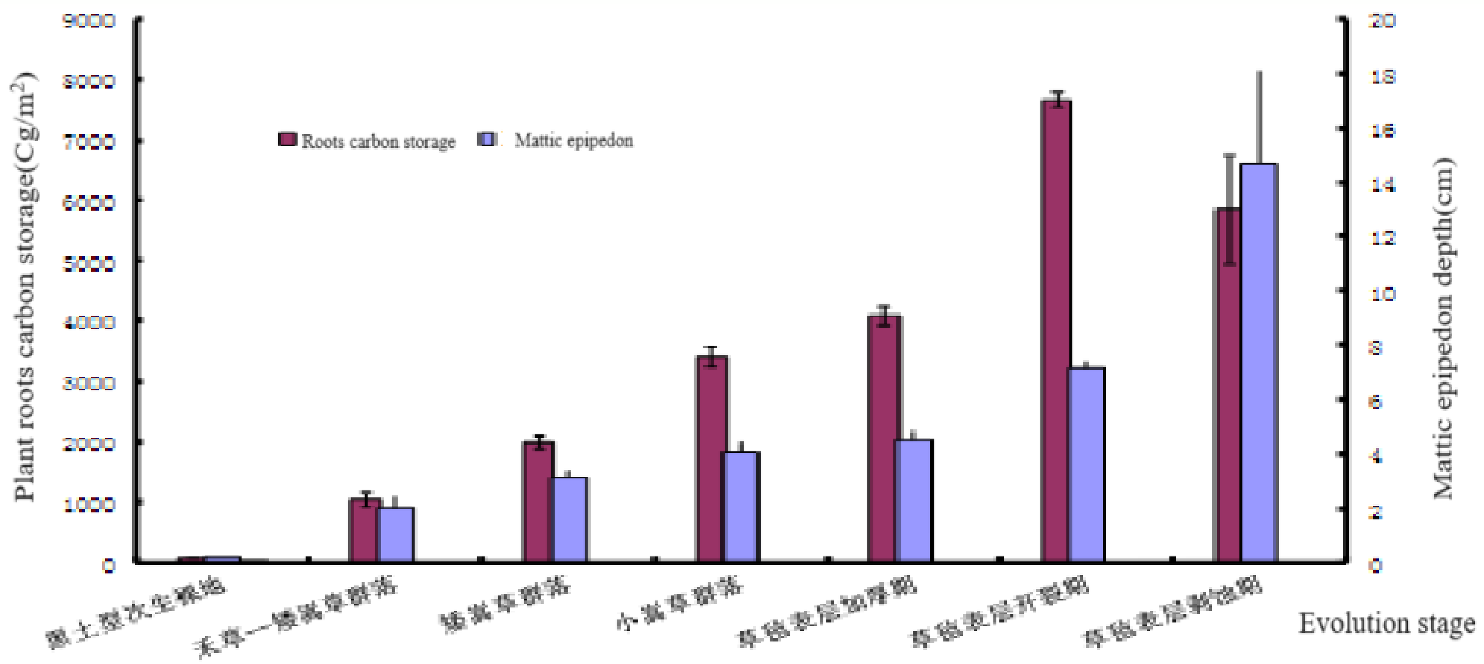
Building artificial vegetation

High cost
Short time
Easy degraded

carbon source → management → carbon sink

3 Carbon budgets based on the utilization of herbivores

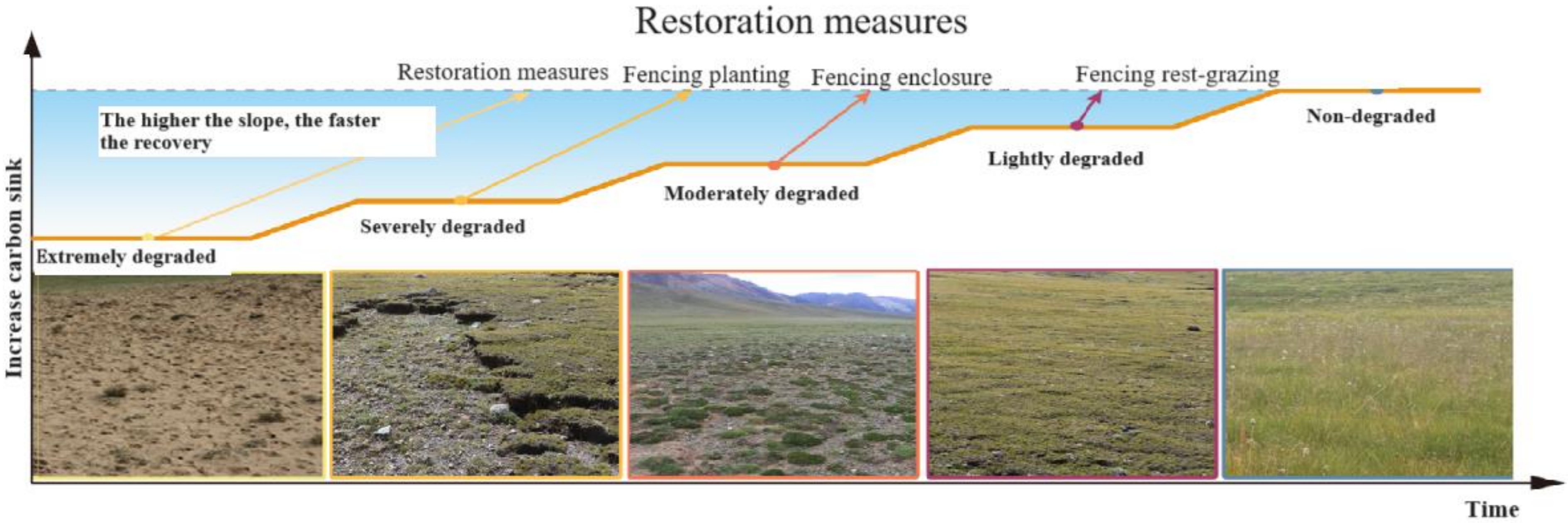
□ Baseline for carbon sequestration and potential carbon capacity in alpine meadows



曹广民等，生态学报，30（23）:6591-6597；林丽等，中国草地学报，2012，42-47

3 Carbon budgets based on the utilization of herbivores

Restoration of grassland degradation carbon sink potential



- Grassland degradation is the main problem facing high-altitude sink enhancement, accounting for 41% of the total grassland area in the region
- If restoration projects are implemented on degraded grasslands, the carbon sequestration potential of degraded grasslands is high, reaching 54.8 TgC per year

孙建等，2021

3 Carbon budgets based on the utilization of herbivores

☐ Regenerated of degraded grasslands and restore carbon sink functions

Mildly degraded grassland

- Reasonable rotational grazing
- Pest control+grazing ban

Severely degraded grassland

- Rodent control+fertilization+prohibition of grazing
- Eliminating impurities and weeds+fertilization+prohibition of grazing
- Pest control+no till and replanting+fertilization+grazing ban

Extremely degraded grassland

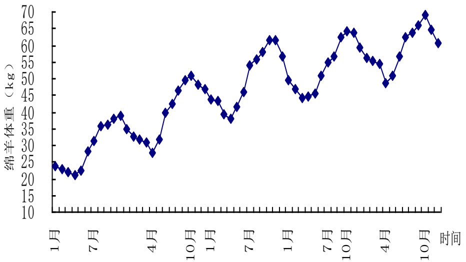
- Rodent control+cutting type artificial grassland
- Rodent control+ecological artificial grassland
- Rodent control+grazing type artificial grassland

Near natural recovery technology → **Semi natural restoration technology** → **Artificial recovery technology**

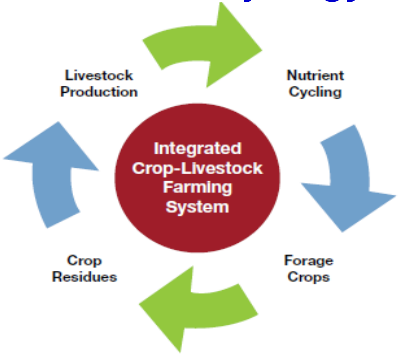
3 major categories and 8 sets of comprehensive recovery and governance technologies

3 Carbon budgets based on the utilization of herbivores

◻ Multifunctionality and Management Practice of Sanjiangyuan Grassland

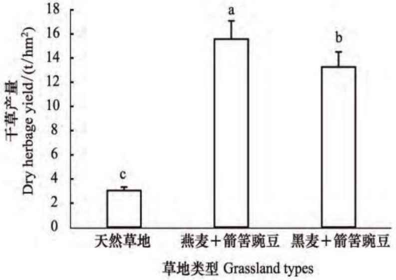


2-6岁（13-27月龄）绵羊体重的变化



优质高产人工草地建植与管理智慧 → 优良牧草青贮技术产业化应用 → 饲草料加工精准配置 → 优质草产品供应 → 草-畜营养均衡保障

New Ecological Animal Husbandry Production Model

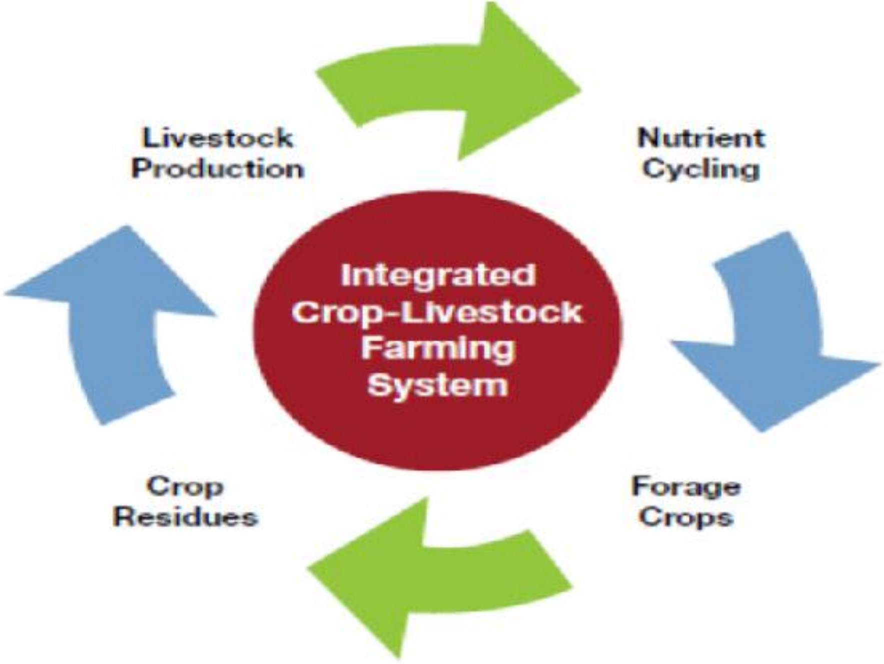


徐田伟等，2000，青藏高原高寒地区生态草牧业可持续发展:原理、技术与实践，生态学报

- Moderate utilization of alpine grasslands
- High quality and high-yield artificial grassland construction
- Excellent forage silage and processing of series grass products
- Accurate allocation of forage and balanced feeding of livestock
- Deep processing of plateau characteristic livestock products
- Regional functional coupling - nutrient balanced feeding - shortening the feeding cycle and reducing grazing pressure.

3 Carbon budgets based on the utilization of herbivores

Sustainable production model in system coupled regions



Balanced feeding, Shorten feeding cycle, Reduce grazing pressure

3 Carbon budgets based on the utilization of herbivores

The carrying capacity of artificial grassland in the peripheral support area

Indicator type	High quality artificial grassland	The source of the Yangtze River Alpine grassland	Kekexili desert steppe
Dry matter production/(t/ha)	15.58	0.72	0.21
Dry matter increase multiple (compared to the Kekexili desert grassland)	74.19	3.43	1.00
Dry matter increase multiple (compared to the high-altitude grassland at the source of the Yangtze River)	21.64	1.00	0.29
Quantity carrying capacity/(SHU/ha·a)	**27.54**	**0.76**	**0.22**
Multiple increase in quantity carrying capacity	**125.18**	3.45	1.00
Winter grass crude protein content/%CP	6.03	3.95	4.32
Total crude protein output/(kg CP/ha)	939.47	28.44	9.07
Multiple increase in total crude protein output	**103.58**	3.13	1.00

3 Carbon budgets based on the utilization of herbivores

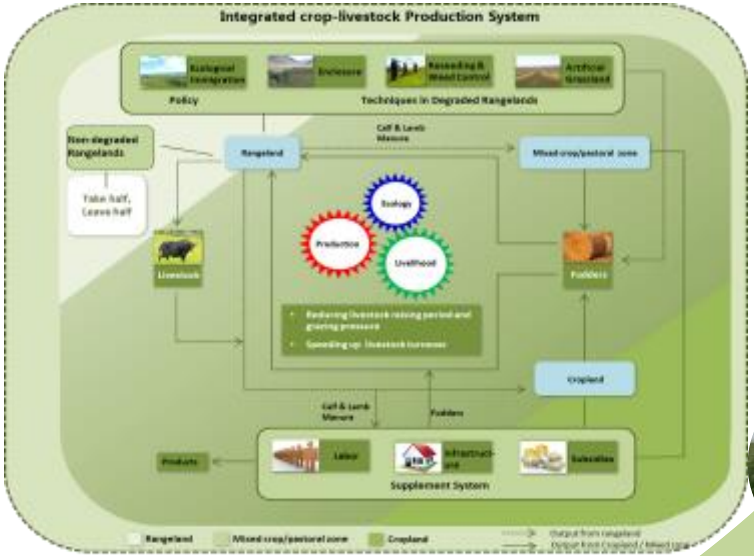
- Transformation from seed based agriculture to nutrient based agriculture in peripheral support areas

- Land transfer + base
- Agro-pastoral Intertwined Zones “Food-fodder change” technical reserve

Smart Solutions for Establishing and Managing High-Quality and High-Yield Artificial Grasslands → Application of Industrialization of High-Quality Forage Silage Technology → Precise feed and forage processing → Quality grass product supply → Grass-animal nutrition balance guarantee

3 Carbon budgets based on the utilization of herbivores

- The reduce carbon emission effected by the "warm grazing and cold feeding" transformative livestock production



- Under the coupling mode of agriculture and animal husbandry, the carbon density per unit of livestock product is 13.81 CO_2 kg-1/
- Greenhouse gas emissions decreased by 23% and economic benefits increased by 6%

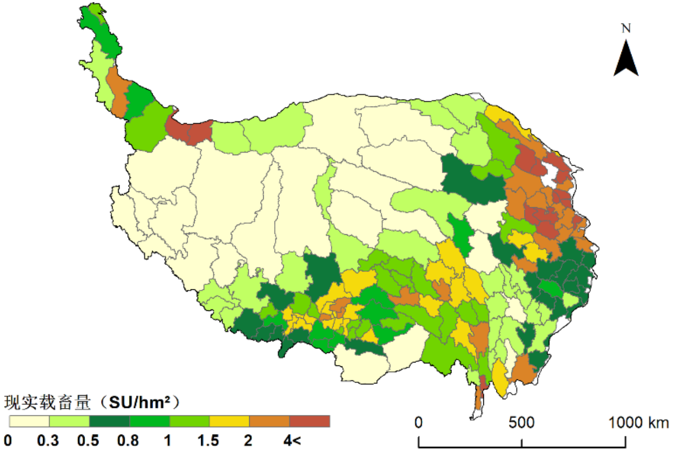
3 Carbon budgets based on the utilization of herbivores

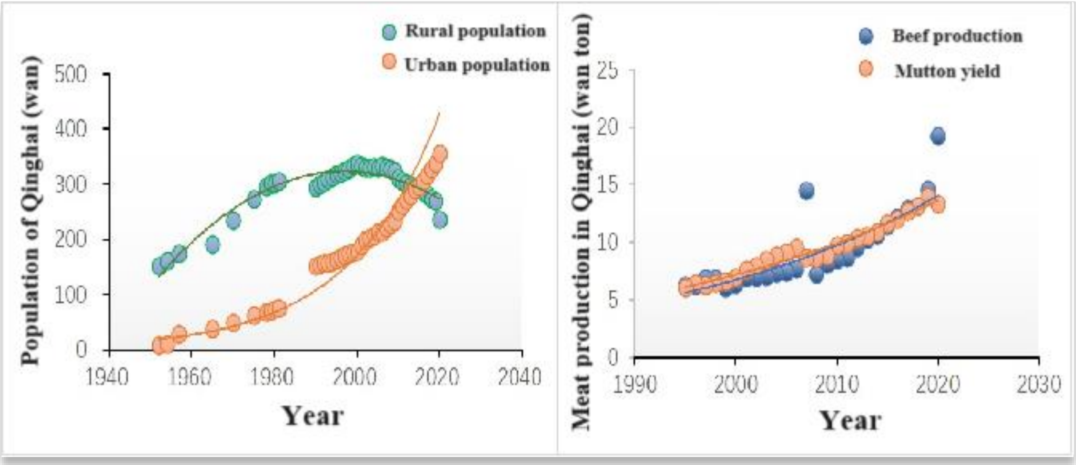
- The method for determining the carrying capacity of grasslands urgently needs improvement,
- Socio economic and grazing utilization will have long-term impacts

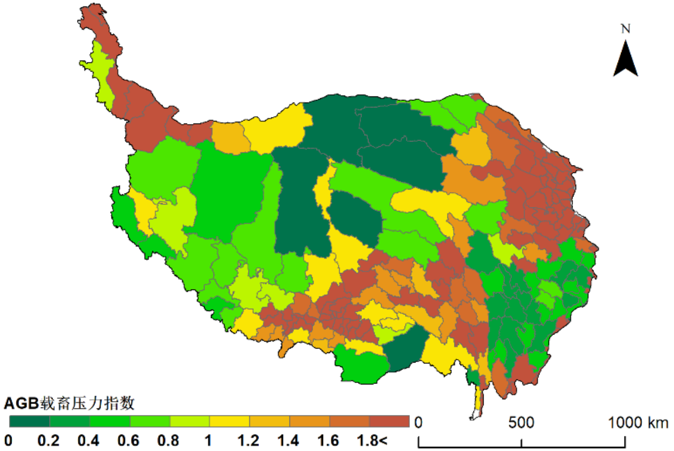
● Realistic livestock carrying capacity considering the structure of cattle and sheep herds: 130.94 million SU

● Theoretical livestock carrying capacity based on grass yield in ground plots: 83.58 million SU

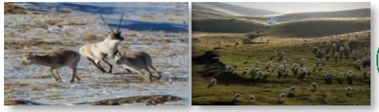
● The average stocking pressure index of the Qinghai-Tibet Plateau is 1.57, of which 1.93 is in Qinghai and 1.18 is in Xizang.



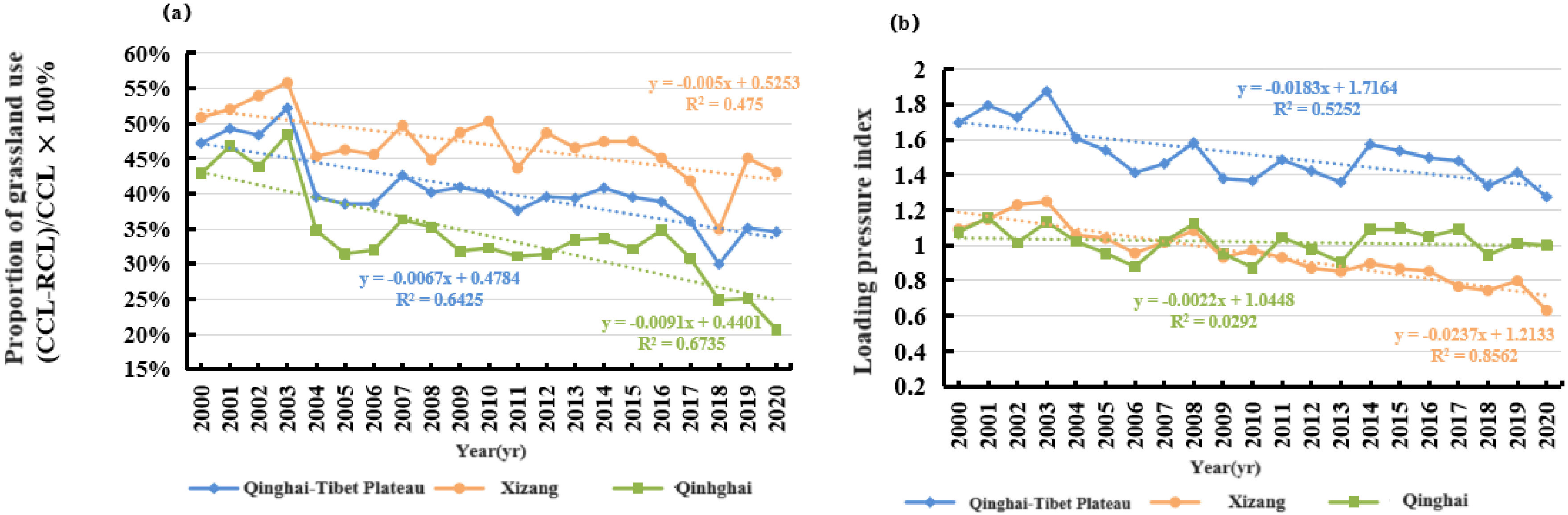




3 Carbon budgets based on the utilization of herbivores



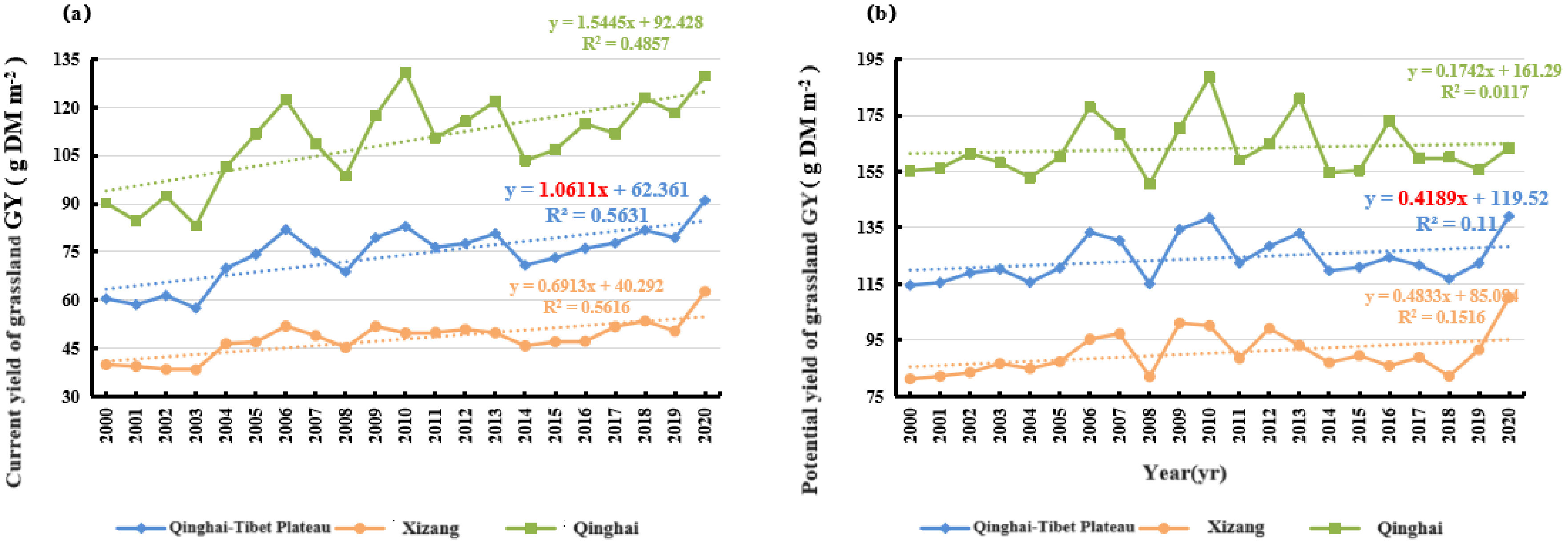
□ Grassland utilization rate and pressure index are decreasing



The proportion of grassland utilization status and the interannual dynamics of livestock carrying pressure index

3 Carbon budgets based on the utilization of herbivores

- Grassland productivity continues to increase, leading to an increase in carbon sequestration capacity



Current grass yield (a) potential grass yield (b) interannual dynamic changes in grassland on the Qinghai-Tibet Plateau from 2000 to 2020


Thanks for your attention !