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MICRO-CREDENTIAL

CLIMATE CHANGE FOR SUSTAINABLE LAND MANAGEMENT IN CENTRAL ASIA

3.- The Carbon Cycle, Land Use and SLM

Carbon Cycle Basics and Land–Atmosphere Interactions

PDF W03

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1. SUMMARY OF KEY IDEAS

This article introduces the carbon cycle as a central process connecting climate change, land use and Sustainable Land Management. Carbon is continuously exchanged between the atmosphere, plants, soils, oceans and geological reservoirs. Some of these exchanges occur rapidly, such as photosynthesis, respiration and decomposition, while others occur slowly over geological time.

Land plays a double role in the carbon cycle. Healthy ecosystems can remove carbon dioxide from the atmosphere and store carbon in vegetation and soils. Degraded land, on the other hand, may lose vegetation cover, reduce soil organic carbon, emit greenhouse gases and weaken ecosystem resilience.

The lesson explains the basic functioning of the carbon cycle, the main carbon pools, and the processes that regulate land–atmosphere interactions. It then focuses on how land-use change, agriculture, overgrazing, deforestation, fire, irrigation and soil degradation can disturb carbon balances.

Special attention is given to Central Asia, where drylands, mountain systems, irrigated agriculture, salinisation, rangeland degradation and the legacy of the Aral Sea crisis create specific challenges for carbon management. Finally, the article presents Sustainable Land Management practices that can protect or increase soil organic carbon, improve water retention, reduce erosion and contribute to climate adaptation and mitigation.

2. LEARNING OBJECTIVES

By the end of this article, the student will be able to:

- Explain the basic structure of the global carbon cycle.
- Distinguish between carbon pools and carbon fluxes.
- Identify the main land–atmosphere carbon exchange processes.
- Explain the roles of photosynthesis, respiration and decomposition.
- Describe the importance of soil organic carbon for soil quality and climate regulation.
- Analyse how land-use change affects carbon storage and greenhouse gas emissions.
- Relate Sustainable Land Management practices to carbon sequestration and climate resilience.
- Identify carbon-cycle challenges specific to Central Asia.
- Discuss the links between carbon management, land degradation, salinity, erosion and water availability.
- Propose basic land management measures that support carbon conservation and climate adaptation.

3. INTRODUCTION

Climate change is often discussed in terms of atmospheric carbon dioxide, temperature increase and greenhouse gas emissions. However, the atmosphere is only one part of the carbon cycle. Carbon moves continuously between air, vegetation, soils, water bodies, oceans, rocks and human systems. This movement determines whether land acts as a carbon sink, storing carbon, or as a carbon source, releasing carbon into the atmosphere.

For students of Sustainable Land Management, understanding the carbon cycle is essential. Land management decisions influence vegetation growth, soil organic matter, erosion, fire risk, water availability and agricultural productivity. All these processes affect the exchange of carbon between land and atmosphere.

Healthy soils and vegetation can store large amounts of carbon. In contrast, degraded soils lose organic matter, become less fertile, retain less water and are more vulnerable to erosion and drought. This creates a negative cycle: land degradation reduces carbon storage, and climate change accelerates land degradation.

In Central Asia, this relationship is particularly important. The region includes extensive drylands, steppe ecosystems, mountain watersheds, irrigated agricultural areas, saline soils and degraded rangelands. Climate change is increasing heat stress, drought risk and water scarcity. At the same time, historical land-use pressures, such as overgrazing, inefficient irrigation and unsustainable cultivation, have reduced the capacity of many landscapes to store carbon and maintain ecosystem functions.

This lesson provides a foundation for understanding the carbon cycle from a land management perspective. It explains the basic science of carbon flows and then connects that science to practical Sustainable Land Management strategies.

4. WHY CARBON MATTERS FOR CLIMATE AND LAND

Carbon is one of the most important elements in the Earth system. It is present in living organisms, soils, rocks, oceans and the atmosphere. It is also a central component of the greenhouse gases that regulate the Earth's temperature.

Carbon matters for climate because carbon dioxide and methane trap part of the heat emitted by the Earth's surface. Without the natural greenhouse effect, the planet would be too cold for life as we know it. However, human activities have increased the concentration of greenhouse gases in the atmosphere, intensifying the greenhouse effect and causing global warming.

Carbon also matters for land because it is a major component of organic matter. Soil organic carbon supports soil structure, fertility, water retention, nutrient cycling and biological activity. In simple terms, carbon is not only a climate variable; it is also a land quality variable.

4.1. Carbon as a basic element of life

Plants absorb carbon dioxide from the atmosphere through photosynthesis and convert it into organic compounds. These compounds form leaves, stems, roots, seeds and fruits. Animals, microorganisms and humans obtain carbon by consuming plants or other organisms.

When organisms respire, die or decompose, carbon returns to the atmosphere, soil or water. Some carbon remains stored in soils for years, decades or centuries. A smaller fraction may become part of long-term geological storage.

This continuous movement of carbon supports life, regulates climate and connects land management with global environmental change.

4.2. Carbon reservoirs and carbon flows

A carbon reservoir, also called a carbon pool, is a place where carbon is stored. Examples include the atmosphere, forests, grasslands, soils, oceans and rocks.

A carbon flow, also called a carbon flux, is the movement of carbon from one reservoir to another. Examples include photosynthesis, respiration, decomposition, fire, erosion, fossil fuel combustion and ocean uptake.

The carbon cycle is therefore not a static system. It is a network of reservoirs connected by flows (Figure 1).

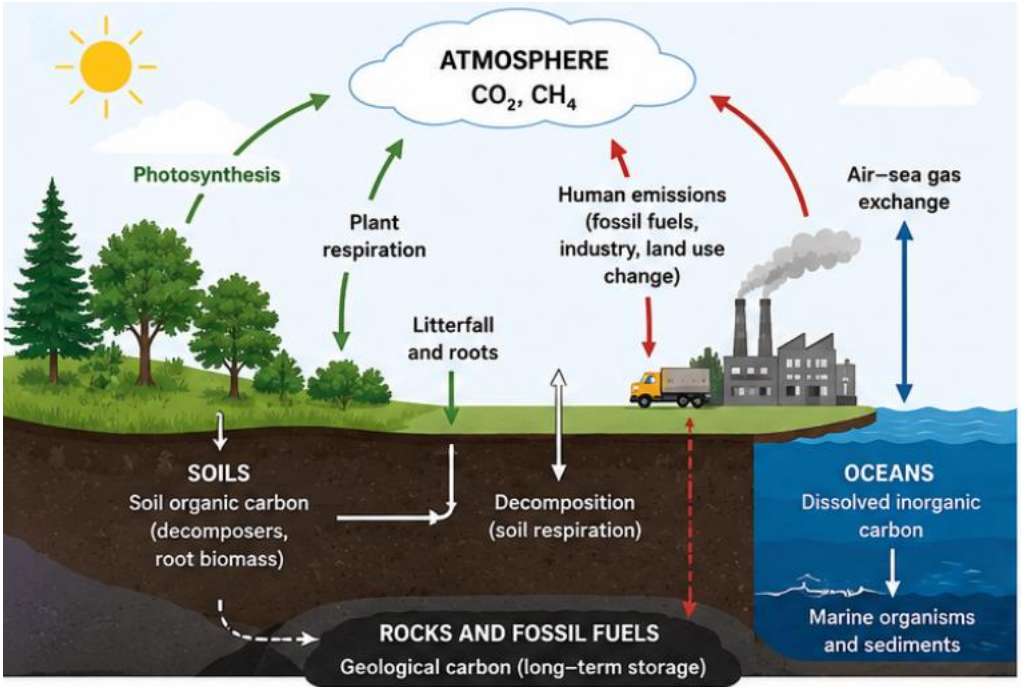


Figure 1. A simplified diagram of the global carbon cycle showing atmosphere, vegetation, soil, oceans, fossil fuels and rocks.

Did you know..? Soils are one of the largest terrestrial carbon reservoirs. This means that soil management is not only important for crop production, but also for climate regulation. A small change in soil organic carbon over a large area can represent a significant carbon gain or loss.

5. THE GLOBAL CARBON CYCLE

The global carbon cycle can be divided into two broad components: the fast carbon cycle and the slow carbon cycle. Both are connected, but they operate at very different time scales.

The fast carbon cycle involves exchanges between the atmosphere, plants, soils and surface waters. These exchanges occur over days, seasons, years or decades. This is the part of the carbon cycle most directly influenced by land management.

The slow carbon cycle involves rocks, sediments, volcanic activity, fossil fuels and long-term geological processes. These processes occur over thousands to millions of years. Human use of fossil fuels has rapidly transferred carbon from geological storage into the atmosphere, disturbing the natural balance of the carbon cycle.

5.1. Fast carbon cycle

The fast carbon cycle is driven mainly by biological processes.

Plants absorb carbon dioxide during photosynthesis. Part of this carbon is used for growth, part returns to the atmosphere through plant respiration, and part enters the soil through roots, litter and crop residues.

Soil organisms decompose organic matter and release carbon dioxide through respiration. Some carbon remains stored in soil organic matter, especially when decomposition is slow or when organic matter is physically protected inside soil aggregates.

This fast cycle is highly sensitive to land use, vegetation cover, soil disturbance, moisture and temperature.

5.2. Slow carbon cycle

The slow carbon cycle includes the movement of carbon through rocks, sediments and fossil fuel deposits. Carbon can be stored for millions of years in limestone, coal, oil, natural gas and other geological formations.

When humans burn fossil fuels, carbon that was stored underground over geological time is released rapidly into the atmosphere as carbon dioxide. This is one of the main causes of contemporary climate change.

Although this lesson focuses mainly on land management, it is important to understand that the climate system responds to both fossil carbon emissions and land-based carbon changes.

5.3. Carbon pools: atmosphere, vegetation, soils, oceans and rocks

The main carbon pools are:

- Atmosphere: stores carbon mainly as carbon dioxide and methane.
- Vegetation: stores carbon in leaves, stems, trunks, roots and plant biomass.
- Soils: store carbon in organic matter, roots, microorganisms and stable soil compounds.
- Oceans: store carbon in dissolved inorganic carbon, marine organisms and sediments.
- Rocks and sediments: store most of the Earth’s carbon over geological time.
- Fossil fuels: store ancient carbon formed from organic matter over millions of years.

For Sustainable Land Management, vegetation and soil are the most relevant pools because they are directly influenced by land-use decisions.

Table 1. Main carbon pools, approximate storage times and relevance for land management.

Carbon pool	Typical form of carbon	Time scale	Relevance for SLM
Atmosphere	CO_2, CH_4	Years to centuries	Determines greenhouse effect
Vegetation	Biomass carbon	Months to decades	Affected by land cover and management
Soil	Soil organic carbon	Years to centuries	Key for fertility and water retention
Ocean	Dissolved carbon	Decades to millennia	Major global carbon sink
Rocks	Carbonates, fossil carbon	Thousands to millions of years	Slow carbon cycle

Reflect Think about a degraded agricultural field and a healthy grassland. Which one is likely to store more carbon in vegetation and soil? Which one is more resilient to drought? Why?

6. LAND–ATMOSPHERE CARBON EXCHANGES

The exchange of carbon between land and atmosphere is controlled by several key processes. The most important are photosynthesis, respiration, decomposition, fire and land disturbance.

These processes determine whether a landscape is a net carbon sink or a net carbon source (Figure 2).

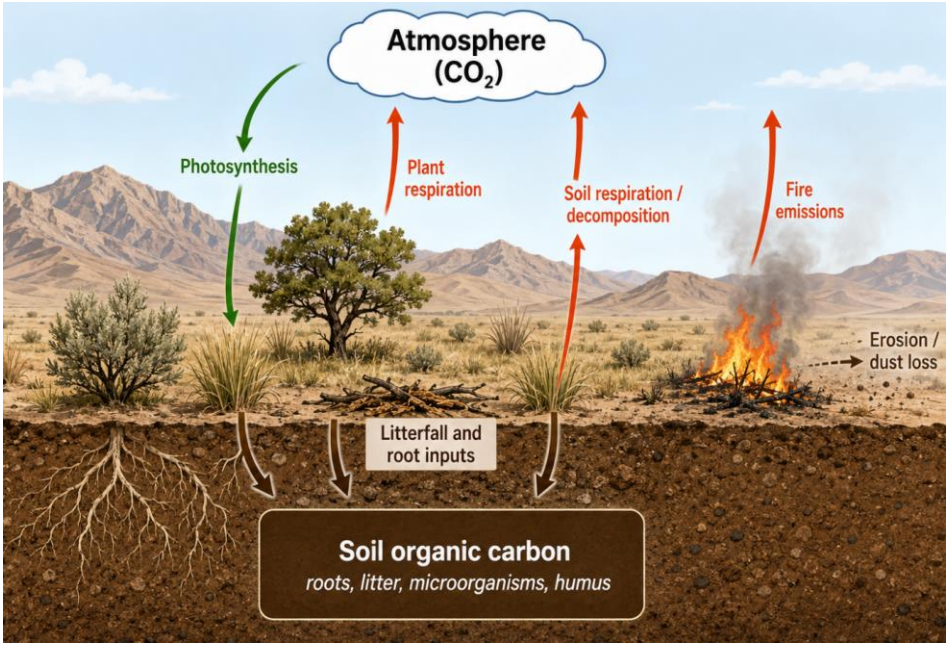


Figure 2. Land–atmosphere carbon exchanges showing photosynthesis, respiration, decomposition, fire and soil carbon storage.

6.1. Photosynthesis

Photosynthesis is the process by which plants use sunlight, water and carbon dioxide to produce organic matter. During this process, carbon dioxide is removed from the atmosphere and transformed into plant biomass.

In land management terms, photosynthesis is the starting point of carbon sequestration. Without plant growth, there is no input of new organic carbon into soils.

Vegetation cover is therefore essential. Grasslands, forests, shrublands, wetlands and croplands all remove carbon dioxide from the atmosphere, although their storage capacity and stability differ.

Land degradation reduces photosynthesis by reducing plant cover, root growth and productivity.

6.2. Plant respiration

Plants also respire. During respiration, plants use energy and release carbon dioxide back into the atmosphere. This is a natural process and does not mean that plants are harmful to the climate.

The carbon balance of vegetation depends on the difference between carbon absorbed through photosynthesis and carbon released through respiration, decomposition or disturbance.

In healthy ecosystems, part of the carbon fixed by plants remains stored in biomass or enters the soil. In degraded systems, less carbon is fixed and more may be lost.

6.3. Soil respiration and decomposition

Soil is biologically active. Microorganisms, fungi, plant roots and soil fauna all respire. They break down organic matter and release carbon dioxide.

Decomposition is necessary for nutrient cycling. It releases nutrients that plants need. However, if decomposition is accelerated by excessive soil disturbance, high temperature, erosion or poor management, soil organic carbon may decline.

Soil respiration increases with temperature and moisture, up to a point. In drylands, decomposition may be limited by lack of water, but when rainfall or irrigation occurs, microbial activity can increase rapidly.

This is particularly relevant in semi-arid regions, where carbon cycling can be strongly pulsed after rainfall or irrigation events.

6.4. Fire, erosion and lateral carbon transport

Carbon can also move through disturbance processes.

Fire rapidly converts biomass and soil organic matter into carbon dioxide, methane, black carbon and ash. Some fire is natural in certain ecosystems, but frequent or severe burning can reduce vegetation cover and soil carbon.

Erosion moves carbon-rich topsoil from one place to another. Part of this carbon may be buried in sediments, but part may be decomposed and released as carbon dioxide. More importantly for land management, erosion removes fertile topsoil and weakens future carbon storage capacity.

Carbon can also be transported laterally through rivers, drainage channels, irrigation systems and dust storms. In Central Asia, wind erosion and salt-dust transport are important pathways linking land degradation and atmospheric processes.



Draw a simple diagram with four boxes: Atmosphere, Plants, Soil and Farmer Management. Add arrows for photosynthesis, respiration, decomposition and tillage. Then indicate which arrows increase carbon storage and which arrows increase carbon loss

7. LAND USE AND CARBON BALANCE

Land use strongly influences carbon balance. A forest, a grassland, a degraded pasture, an irrigated crop field and a saline abandoned field do not store or exchange carbon in the same way.

The key question is whether land management increases carbon inputs, reduces unnecessary losses, protects soil structure and maintains vegetation cover.

7.1. Forests and shrublands

Forests and shrublands store carbon in aboveground biomass, roots, litter and soils. Trees and shrubs can store carbon for decades or centuries, depending on species, climate, disturbance and management.

In drylands, shrublands and sparse forests may store less carbon per hectare than humid forests, but they can still play an important role in soil protection, microclimate regulation and erosion control.

Afforestation and reforestation can increase carbon storage when they are ecologically appropriate. However, planting trees without considering water availability can create problems in arid and semi-arid regions. Tree species must be adapted to local climate, soil and water conditions.

7.2. Grasslands and rangelands

Grasslands and rangelands store a large proportion of their carbon below ground, in roots and soil organic matter. This makes them especially important for dryland carbon management.

Sustainable grazing can maintain plant cover, stimulate root growth and support soil carbon. Overgrazing, however, removes vegetation, compacts soil, increases erosion and reduces organic matter inputs.

In Central Asia, rangelands are extensive and support rural livelihoods. Their management is central to both climate resilience and land degradation control.

7.3. Croplands

Croplands can either lose or store soil carbon depending on management.

Conventional intensive tillage often accelerates the loss of soil organic carbon by breaking soil aggregates, exposing organic matter to decomposition and increasing erosion risk.

On the other hand, conservation agriculture, crop rotations, cover crops, residue retention, organic amendments and reduced tillage can help maintain or increase soil carbon.

Croplands are also connected to greenhouse gas emissions through fertiliser use, irrigation, energy consumption and soil disturbance. Therefore, carbon management in croplands must be integrated with nutrient and water management.

7.4. Irrigated agriculture

Irrigated agriculture is a special case. Irrigation can increase plant growth and carbon inputs if water is well managed. However, inefficient irrigation can also cause waterlogging, salinity, soil degradation and loss of productivity.

In semi-arid regions, irrigation may increase biomass production, but only if drainage, salinity and nutrient management are adequate. If salinity increases, plant growth declines, organic matter inputs decrease and soil structure may deteriorate.

Irrigated agriculture must therefore be considered as both an opportunity and a risk for carbon management.

7.5. Wetlands and riparian areas

Wetlands and riparian zones can store significant carbon because waterlogged conditions often slow decomposition. However, drainage of wetlands can release stored carbon as carbon dioxide and, in some cases, increase emissions of other greenhouse gases.

In Central Asia, wetlands, river corridors and delta systems have been strongly affected by water diversion, irrigation and land-use change. Protecting and restoring these areas can support biodiversity, water regulation and carbon storage.



Not every land-based carbon project is automatically sustainable. For example, planting trees in a water-scarce area may reduce water availability for local communities or ecosystems. Sustainable carbon management must consider water balance, biodiversity, land rights and local livelihoods.

8. SOIL ORGANIC CARBON AND SUSTAINABLE LAND MANAGEMENT

Soil organic carbon is the carbon component of soil organic matter. It comes from plant residues, roots, manure, compost, microorganisms and decomposed biological material.

It is one of the most important indicators of soil health (Figure 3).

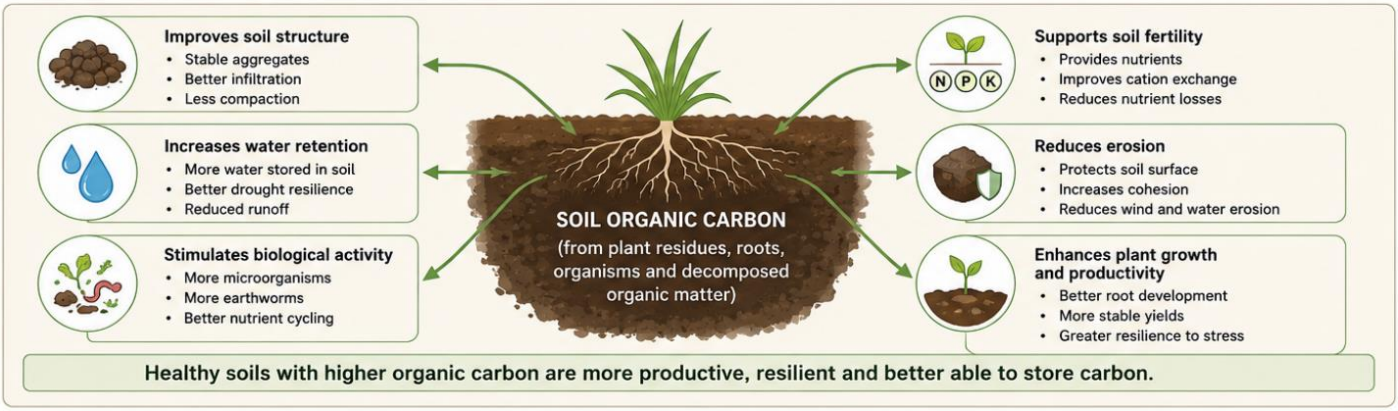


Figure 3. Soil organic carbon and soil functions diagram, showing links between organic matter, water retention, fertility, structure and erosion resistance.

8.1. What is soil organic carbon?

Soil organic carbon is stored in different forms. Some of it is fresh and easily decomposed, such as crop residues or young roots. Some are more stable, protected inside soil aggregates or associated with clay minerals.

The stability of soil carbon depends on climate, soil texture, mineralogy, vegetation, land use and management. Clay soils often protect organic carbon more effectively than sandy soils. Dry climates may slow down decomposition, but low vegetation productivity can also limit carbon inputs.

8.2. Soil carbon, soil fertility and water retention

Soil organic carbon improves several key soil properties:

- Soil structure.
- Water infiltration.
- Water-holding capacity.
- Nutrient cycling.
- Biological activity.
- Resistance to erosion.
- Root development.
- Crop productivity.
- Drought resilience.

In semi-arid regions, the water-related benefits of soil organic carbon are particularly important. Soils with more organic matter can retain more moisture, reduce runoff and support plant growth during dry periods.

This means that soil carbon is both a climate mitigation issue and an adaptation issue.

8.3. Soil carbon loss and land degradation

Soil carbon can be lost through:

- Intensive tillage.
- Removal or burning of crop residues.
- Overgrazing.
- Deforestation.
- Erosion.
- Salinisation.
- Waterlogging.
- Declining vegetation cover.
- Poor nutrient management.
- Repeated drought and heat stress.

When soil carbon declines, soil becomes less fertile and less resilient. It may form crusts, erode more easily and retain less water. This reduces plant growth, which further reduces carbon inputs. The result is a degradation feedback loop.

Did you know..?

Soil organic carbon is not only important because it stores carbon. It also improves the physical and biological quality of soil. This is why carbon-rich soils are usually more productive, more resilient and better able to support Sustainable Land Management..

9. CARBON CYCLE DISTURBANCE IN CENTRAL ASIA

Central Asia includes Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. The region contains large drylands, steppe landscapes, mountain systems, irrigated valleys and desert areas. These environments are highly sensitive to climate and land-use change.

The carbon cycle in Central Asia is influenced by water availability, vegetation cover, soil degradation, salinity, grazing pressure and irrigation management (Figure 4).



Figure 4. Map of Central Asia showing drylands, major river basins, irrigated areas and mountain water towers.

9.1. Drylands, steppes and mountain systems

Drylands cover a large part of Central Asia. In drylands, carbon storage is usually limited by water availability. When rainfall is low or irregular, plant productivity is limited and carbon inputs to soil are reduced.

Steppe and rangeland ecosystems store much of their carbon below ground. Their root systems are essential for soil structure and organic matter accumulation. Degradation of these systems can therefore cause significant carbon loss from soils.

Mountain systems are also important. They influence water supply, vegetation patterns and erosion. Climate change affects snow and glacier dynamics, which in turn affects downstream irrigation, wetlands and agricultural productivity.

9.2. Overgrazing and vegetation loss

Overgrazing is one of the most important land degradation pressures in many rangeland areas. When grazing intensity exceeds the capacity of the ecosystem, vegetation cover declines.

This can produce several carbon-related effects:

- Less photosynthesis.
- Lower root biomass.
- Reduced organic matter inputs.
- More soil compaction.
- Higher erosion risk.
- Lower soil water infiltration.
- Reduced soil carbon storage.

Sustainable grazing management does not mean eliminating livestock. It means adjusting stocking rates, grazing duration, seasonal movement and pasture recovery to maintain vegetation and soil function.

9.3. Irrigation, salinity and soil carbon

Irrigated agriculture is essential in several Central Asian countries, especially in lowland river basins. However, irrigation systems can affect the carbon cycle in different ways.

Well-managed irrigation can increase biomass production and carbon inputs. Poorly managed irrigation can cause waterlogging, salinity and soil degradation.

Salinity reduces plant growth and weakens soil biological activity. If crop productivity declines, less organic material returns to the soil. Over time, saline soils may lose fertility and carbon.

In this sense, salinity is not only a water or soil chemistry problem. It is also connected to carbon cycling and land productivity.

9.4. The Aral Sea basin and dust transport

The Aral Sea basin illustrates the interaction between water management, land degradation and atmospheric processes. Large-scale water diversion reduced inflows to the sea, exposed former seabed areas and contributed to salt and dust transport.

Dust storms can move salts, sediments and pollutants over long distances. This affects soils, crops, vegetation and human health. It also represents a lateral movement of material from degraded land into the atmosphere and surrounding landscapes.

While dust transport is not usually the first process considered in the carbon cycle, it is part of the broader land–atmosphere interaction system. Loss of vegetation and soil structure increases both dust emissions and carbon vulnerability.



Select one Central Asian landscape: steppe rangeland, irrigated cotton field, mountain pasture, saline lowland or riparian wetland. How does this landscape store carbon? What land-use pressure could turn it from a carbon sink into a carbon source?

10. SLM PRACTICES THAT SUPPORT CARBON MANAGEMENT

Sustainable Land Management can support carbon storage while also improving soil fertility, water management and climate resilience. The aim is not only to store carbon, but to maintain productive and functional landscapes.

10.1. Conservation agriculture

Conservation agriculture is based on three general principles:

- Minimal soil disturbance.
- Permanent or semi-permanent soil cover.
- Crop diversification.

These practices can reduce erosion, protect soil aggregates, increase organic matter inputs and improve water retention. In semi-arid areas, conservation agriculture can also help conserve soil moisture.

However, implementation depends on local conditions. Farmers may face barriers such as lack of equipment, crop residue needs for livestock, weed pressure or limited advisory services.

10.2. Sustainable grazing management

Sustainable grazing management aims to maintain vegetation cover and root systems while supporting livestock production.

Useful measures include:

- Rotational grazing.
- Seasonal pasture planning.
- Rest periods for degraded areas.
- Protection of highly erodible zones.
- Improved water point distribution.
- Reseeding or restoration where needed.
- Community-based pasture management.

These measures can increase plant recovery, reduce erosion and support soil carbon storage.

10.3. Afforestation, reforestation and shelterbelts

Tree and shrub planting can support carbon storage, wind erosion control and microclimate regulation. In Central Asia, shelterbelts and windbreaks can protect agricultural fields from wind erosion and dust.

However, tree planting must be ecologically appropriate. Species selection, water demand, soil salinity and long-term maintenance are critical.

In arid areas, native drought-tolerant species are often more suitable than fast-growing exotic species with high water requirements.

10.4. Restoration of degraded land

Restoration aims to recover ecological function in degraded land. It may include vegetation recovery, erosion control, soil amendments, salinity management, drainage rehabilitation or assisted natural regeneration.

Restoration can increase carbon storage by re-establishing plant cover and improving soil organic matter. It can also reduce dust, improve water infiltration and support biodiversity.

The carbon benefits of restoration are often long-term. Monitoring is needed to evaluate whether vegetation cover, soil carbon and productivity actually improve.

10.5. Improved irrigation and salinity control

In irrigated areas, carbon management must be linked to water and salinity management.

Relevant measures include:

- Efficient irrigation scheduling.
- Canal maintenance.
- Drainage rehabilitation.
- Avoiding over-irrigation.
- Monitoring soil salinity.
- Using appropriate leaching practices.
- Improving field levelling.
- Selecting salt-tolerant crops where needed.
- Combining water management with organic matter improvement.

Reducing salinity can help restore plant productivity and increase organic inputs to soil.

10.6. Organic amendments and circular biomass use

Organic amendments such as compost, manure or crop residues can increase soil organic matter and improve soil structure. They can also support circular economy approaches by returning biomass to land instead of treating it as waste.

However, organic amendments must be managed carefully. Contaminated compost, excessive manure or poorly treated sludge may introduce salts, pathogens, metals or organic pollutants.

Carbon management must therefore be linked to soil quality protection.

Table 2. SLM practices and their carbon benefits.

SLM practice	Carbon effect	Additional benefit	Possible limitation
Reduced tillage	Protects soil organic carbon	Reduces erosion	May require equipment
Residue retention	Adds organic matter	Improves moisture	Residues may be needed for livestock
Rotational grazing	Maintains vegetation cover	Improves pasture recovery	Requires coordination
Shelterbelts	Store biomass carbon	Reduce wind erosion	Need water and maintenance

Drainage rehabilitation	Reduces salinity stress	Improves crop productivity	Requires investment
Compost application	Adds organic carbon	Improves soil structure	Quality control needed



Choose one SLM practice from Table 2. Write three sentences explaining:

1. How it affects the carbon cycle.
2. How it supports adaptation to climate change.
3. What barrier may limit its implementation in Central Asia.

11. MONITORING CARBON IN LAND MANAGEMENT

Carbon management requires monitoring. Without monitoring, it is difficult to know whether land management practices are increasing carbon storage, reducing degradation or improving resilience.

Monitoring does not always require complex equipment, but it does require consistent methods, repeated observations and clear indicators.

11.1. Field measurements

Field measurements may include:

- Soil organic carbon sampling.
- Bulk density measurement.
- Vegetation cover assessment.
- Biomass estimation.
- Root biomass studies.
- Soil moisture monitoring.
- Erosion measurements.
- Crop yield records.
- Salinity measurements.
- Land management records.

Soil organic carbon measurement requires careful sampling because carbon varies with depth, soil type, land use and management history. Comparing carbon between sites requires consistent sampling depth and laboratory methods.

11.2. Remote sensing

Remote sensing can help monitor vegetation cover, productivity, land cover change, burn scars, erosion risk and restoration progress.

Satellite indicators such as NDVI are often used to estimate vegetation condition. However, remote sensing cannot directly measure soil organic carbon in all cases. It must often be combined with field data, soil maps and models.

For large regions such as Central Asia, remote sensing is especially useful because field monitoring networks may be sparse and landscapes are extensive.

11.3. Indicators and reporting

Carbon-related indicators may include:

- Soil organic carbon stock.
- Vegetation cover.
- Net primary productivity.
- Land productivity dynamics.
- Area restored.
- Area under sustainable grazing.
- Area under conservation agriculture.
- Aboveground biomass.
- Erosion rate.
- Salinity-affected area.

These indicators can support national reporting, project evaluation and land degradation monitoring.

Carbon monitoring is also linked to Land Degradation Neutrality, climate adaptation planning and international climate commitments.



Carbon indicators should not be interpreted in isolation. A project may increase carbon but reduce biodiversity, water availability or local access to land. Sustainable Land Management requires multiple indicators, including soil, water, biodiversity, productivity and social impacts.

12. CONCLUSIONS

The carbon cycle connects atmosphere, vegetation, soils, oceans and geological reservoirs. For Sustainable Land Management, the most important part of this cycle is the exchange of carbon between land and atmosphere through photosynthesis, respiration, decomposition, disturbance and soil organic matter formation.

Land can function as a carbon sink when vegetation is healthy, soils are protected and organic matter is maintained. It can become a carbon source when land is degraded, vegetation is removed, soils are eroded, fires increase or organic matter declines.

In Central Asia, carbon-cycle management is closely linked to dryland resilience, rangeland condition, irrigation management, salinity control, restoration of degraded land and adaptation to climate change. The region's extensive steppes, mountain systems, irrigated valleys and degraded landscapes make Sustainable Land Management a strategic tool for both mitigation and adaptation.

Soil organic carbon is a particularly important concept because it connects climate regulation with soil fertility, water retention and agricultural productivity. Protecting soil carbon is therefore not only a climate objective, but also a practical requirement for maintaining land-based livelihoods.

The main lesson is that carbon management cannot be separated from land management. Every decision about grazing, irrigation, tillage, crop residues, restoration, forestry or soil protection influences the carbon cycle. Sustainable Land Management provides the practical framework for turning carbon-cycle knowledge into field-level action.

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