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CLIMATE CHANGE FOR SUSTAINABLE LAND MANAGEMENT IN CENTRAL ASIA

6.- Agriculture, Food Security and Rural Livelihoods

Climate Change and Agricultural Systems in Central Asia

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1. SUMMARY OF KEY IDEAS

This article explains how climate change affects agricultural systems, food security and rural livelihoods in Central Asia. Agriculture is one of the sectors most directly exposed to climate variability because crop growth, livestock productivity, soil quality and water availability depend on temperature, precipitation, snowmelt, irrigation supply and seasonal stability.

The lesson introduces the relationship between agriculture and climate, paying attention to both directions of this relationship. On the one hand, agriculture is affected by climate change through heat stress, drought, water scarcity, soil salinity, pests, diseases and extreme events. On the other hand, agricultural systems contribute to greenhouse gas emissions through land-use change, livestock, fertiliser use, irrigation energy and soil degradation.

Food security is analysed through four pillars: availability, access, utilisation and stability. Climate change can affect all four. It can reduce production, increase price volatility, weaken rural incomes, affect nutrition and increase the risk of food-system disruptions.

The lesson then focuses on Central Asia, where irrigated agriculture, rainfed farming, rangelands and mountain agriculture face different climate risks. Particular attention is given to water scarcity, soil moisture deficit, salinisation, rangeland degradation and the vulnerability of rural households.

Finally, the article presents Sustainable Land Management and climate-smart agriculture practices that can strengthen resilience. These include improved irrigation, soil conservation, crop diversification, pasture management, agroforestry, shelterbelts, early warning systems, extension services and institutional support.

2. LEARNING OBJECTIVES

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

- Explain why agricultural systems are highly sensitive to climate variability and climate change.
- Describe the four pillars of food security and how they may be affected by climate change.
- Identify the main agricultural systems in Central Asia.
- Analyse how drought, heat stress, water scarcity and salinity affect crop production.
- Explain the links between land degradation, rural livelihoods and climate vulnerability.
- Identify how pastoral systems and rangelands are exposed to climate risks.
- Describe climate-smart agriculture and its relationship with Sustainable Land Management.
- Propose practical adaptation measures for farmers and rural communities.

- Recognise the importance of extension services, early warning and local institutions.
- Select basic indicators to monitor agricultural resilience under climate change.

3. INTRODUCTION

Agriculture is one of the clearest examples of the connection between climate and land management. Crops need suitable temperatures, sufficient water, healthy soils and stable growing seasons. Livestock systems depend on pasture productivity, water access, animal health and seasonal mobility. Rural households depend on the success of these systems for income, food, employment and social stability.

Climate change is modifying the conditions under which agriculture operates. Higher temperatures, altered precipitation, more frequent droughts, glacier retreat, changing snowmelt patterns and extreme weather events are already affecting agricultural systems in many regions of the world. In Central Asia, these impacts are especially important because agriculture depends heavily on irrigation, mountain water resources, dryland ecosystems and fragile soils.

Central Asia includes highly diverse agricultural landscapes: irrigated lowlands, rainfed cereal areas, mountain valleys, steppe rangelands, desert margins and peri-urban food production areas. Each system has different vulnerabilities. Irrigated agriculture is strongly exposed to water scarcity and salinity. Rainfed agriculture is exposed to rainfall variability and drought. Pastoral systems are exposed to pasture degradation, heat stress and water shortages. Mountain agriculture is affected by snow, glacier dynamics, erosion and short growing seasons.

This lesson explains how climate change affects agricultural production and rural livelihoods, and how Sustainable Land Management can help reduce risks. It does not treat agriculture only as a production system, but as a socio-ecological system where land, water, climate, labour, markets, institutions and knowledge interact.

4. AGRICULTURE, CLIMATE AND LAND MANAGEMENT

Agriculture depends directly on climate. Temperature influences crop development, flowering, grain filling, evapotranspiration and animal heat stress. Precipitation influences soil moisture, pasture growth, river runoff and groundwater recharge. Wind, storms, frost, hail and heatwaves can damage crops and infrastructure.

Climate change does not affect agriculture through one single pathway. It changes the average conditions, such as mean temperature, but also the variability and frequency of extreme events. For farmers, the timing of climate events can be as important as their magnitude. A heatwave during flowering may

damage crop yield more severely than the same temperature occurring outside the sensitive growth period.

4.1. Why agriculture is climate-sensitive

Agricultural systems are climate-sensitive because biological processes operate within specific environmental ranges. Crops have optimal temperature ranges. Livestock have thermal comfort limits. Soil organisms depend on moisture and temperature. Irrigation systems depend on river flows, reservoirs, canals, groundwater and energy.

A small climatic change can produce a large agricultural impact when it occurs at a critical moment. For example:

- A dry spring may reduce germination.
- A heatwave during flowering may reduce grain formation.
- A drought during pasture growth may reduce forage availability.
- A warm winter may affect fruit trees that require chilling.
- A flood may destroy irrigation infrastructure or erode fertile soil.

Agriculture is therefore not only sensitive to annual climate averages. It is sensitive to seasonal patterns, thresholds and extreme events.

4.2. Agriculture as both affected sector and emitting sector

Agriculture is affected by climate change, but it also contributes to climate change. This dual role is important.

Agricultural emissions can come from:

- Methane from livestock.
- Methane from some flooded agricultural systems.
- Nitrous oxide from fertiliser and manure.
- Carbon dioxide from fuel use and irrigation pumping.
- Carbon loss from soil degradation.
- Land-use change and vegetation removal.
- Burning of crop residues.
- Decomposition of organic matter after soil disturbance.

At the same time, well-managed agricultural land can store carbon in soil, roots, trees and vegetation. This means that agriculture can be part of both the problem and the solution.

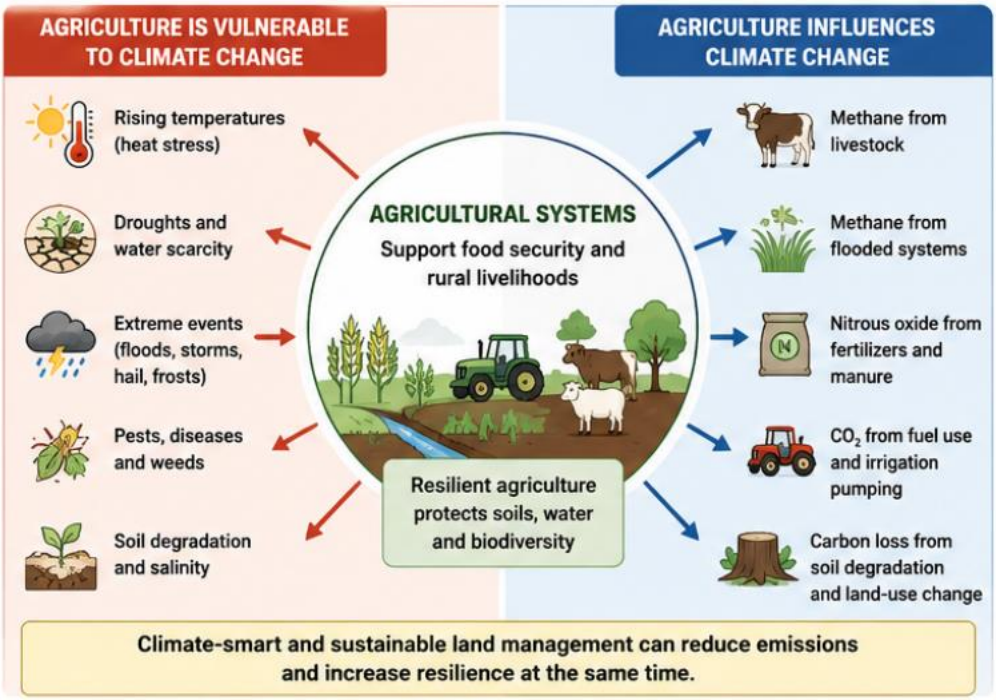


Figure 1. Diagram showing agriculture as both climate-vulnerable and climate-influencing.

Did you know..? Agriculture is one of the few sectors that is simultaneously affected by climate change, contributes to greenhouse gas emissions, and can help remove carbon from the atmosphere through improved soil and vegetation management.

5. FOOD SECURITY AND CLIMATE CHANGE

Food security does not mean only producing enough food. It also means that people can access food, use it safely and nutritionally, and rely on stable supplies over time.

Climate change affects food security through agricultural production, water availability, market prices, food quality, rural incomes and infrastructure. It may also increase the risk of simultaneous shocks, such as drought combined with high food prices or water shortages combined with crop disease.

5.1. The four pillars of food security

Food security is commonly explained through four pillars:

1. **Availability**
   The physical supply of food, including domestic production, imports, storage and distribution.
2. **Access**
   The ability of households to obtain food through income, markets, own production or social support.
3. **Utilisation**
   The safe and nutritious use of food, including diet quality, food safety, clean water, sanitation and health.
4. **Stability**
   The reliability of availability, access and utilisation over time, including resistance to shocks and seasonal shortages.

Climate change can affect all four pillars.

For example, drought may reduce cereal production. This affects availability. If prices rise, poor households may lose access. If water quality declines, food utilisation and health may be affected. If droughts become more frequent, food stability is weakened.

5.2. Climate risks to food availability

Food availability is directly affected by changes in crop and livestock production. Higher temperatures can reduce yields when they exceed crop tolerance thresholds. Drought reduces soil moisture and irrigation supply. Floods can damage fields and infrastructure. Pests and diseases may expand into new areas.

In Central Asia, food availability depends on both local production and regional trade. Wheat, cotton, fruits, vegetables, livestock products and fodder crops are all influenced by climate conditions.

In irrigated areas, production may remain high when water is available. However, if water becomes scarce during the growing season, crops may face stress precisely when they most need irrigation. In rainfed areas, yield variability may increase with changing precipitation patterns.

5.3. Climate risks to food access, utilisation and stability

Food access depends strongly on income. If farmers lose harvests or livestock productivity declines, household income may fall. Rural labour demand may also decrease during bad seasons. Food prices may rise when production falls or transport is disrupted.

Food utilisation can be affected when climate change reduces water quality, increases food spoilage, affects diet diversity or increases disease risk. Heat can increase food storage problems, and water scarcity can reduce hygiene.

Food stability is affected when shocks become more frequent. A rural household may recover from one bad year, but repeated droughts, livestock losses, crop failures or price shocks can erode savings and increase vulnerability.

Table 1. Climate impacts on the four pillars of food security.

Food security pillar	Climate-related pressure	Example in agricultural systems
Availability	Lower crop yields	Drought reduces wheat or fodder production
Access	Lower income or higher prices	Farmers lose income after crop failure
Utilisation	Lower diet quality or unsafe water	Reduced vegetable production and poor water quality
Stability	More frequent shocks	Repeated droughts reduce household resilience



Think about your own country or region. Which pillar of food security is most vulnerable to climate change: availability, access, utilisation or stability? Explain your answer with one example

6. AGRICULTURAL SYSTEMS IN CENTRAL ASIA

Central Asia's agricultural systems are diverse. They include irrigated agriculture in river basins and oases, rainfed cropping in steppe zones, pastoralism across rangelands, and mountain agriculture in valleys and uplands.

These systems are connected. Irrigated lowlands depend on water generated in mountain areas. Pastoral systems may depend on seasonal movement between lowland and highland pastures. Crop systems depend on soils, irrigation, fertiliser, labour, machinery and markets.

6.1. Irrigated agriculture

Irrigated agriculture is central to several Central Asian economies. It supports crops such as cotton, wheat, rice, vegetables, orchards and fodder. In dry lowland areas, irrigation often makes agriculture possible.

However, irrigated agriculture is highly exposed to climate-related water risks. River flows may change due to snowmelt shifts, glacier retreat, reservoir operation, drought and upstream water use. Higher temperatures increase crop water demand and evapotranspiration.

Irrigation also interacts with land degradation. Poor drainage and excessive irrigation can raise groundwater tables and increase salinity. Salinity reduces crop productivity and may push farmers to apply more water or fertiliser, which can worsen the problem.

6.2. Rainfed agriculture

Rainfed agriculture depends directly on precipitation and soil moisture. It is common in areas where rainfall is sufficient for cereal production or pasture growth, but it is highly sensitive to drought.

Climate change can affect rainfed agriculture through:

- Reduced rainfall reliability.
- Higher evapotranspiration.
- More frequent dry spells.
- Heat stress during crop development.
- Increased soil erosion during intense rainfall.
- Greater yield variability.

Rainfed farmers often have fewer options to manage water risk than irrigated farmers. Soil moisture conservation is therefore essential.

6.3. Pastoral and rangeland systems

Pastoral systems and rangelands are essential for rural livelihoods across much of Central Asia. Livestock production depends on pasture condition, water points, seasonal mobility, fodder availability and animal health.

Climate risks include:

- Drought reducing pasture biomass.
- Heat stress affecting animals.
- Snow or ice events limiting access to forage.
- Water shortages at pasture points.
- Degradation around settlements and wells.
- Reduced mobility due to land-use changes or institutional constraints.

Pastoral systems are adaptive by nature when mobility, local knowledge and pasture governance function well. However, when mobility is restricted and pasture pressure increases, climate shocks can become more damaging.

6.4. Mountain agriculture

Mountain agriculture includes small-scale cropping, orchards, livestock, hay meadows and pasture systems. It is often highly sensitive to climate because slopes, erosion, short growing seasons and water sources constrain production.

Climate change can produce both opportunities and risks in mountain areas. Warmer temperatures may lengthen the growing season in some locations, but they may also increase pests, water stress, landslides, glacier-related hazards and erosion.

Mountain communities often have limited land, limited infrastructure and high exposure to natural hazards. This makes livelihood resilience especially important.

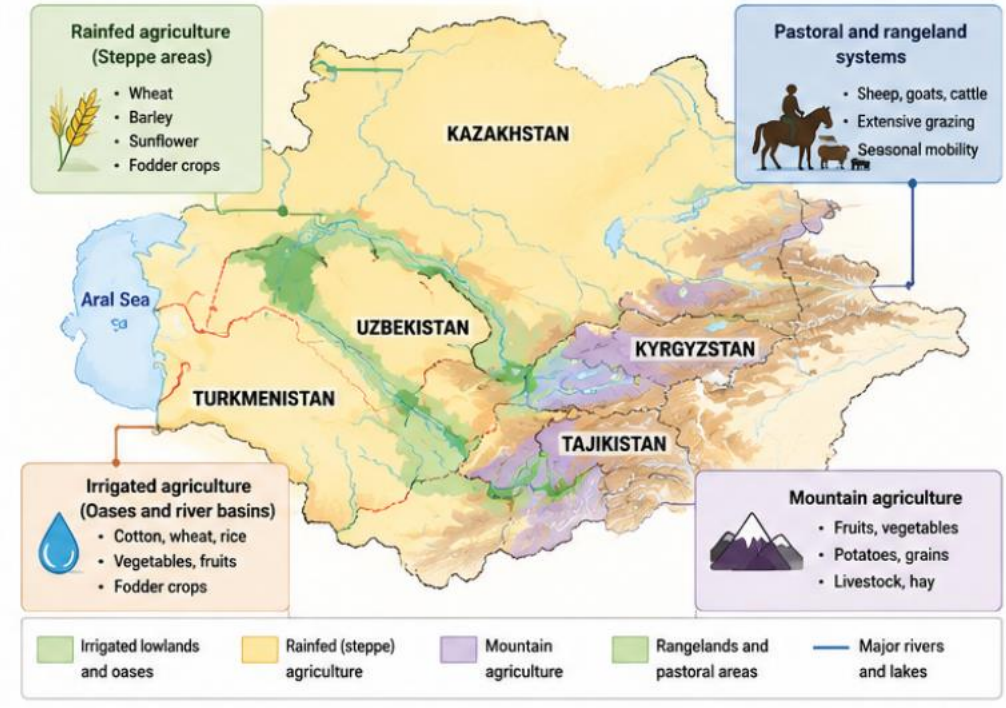


Figure 2. Map or schematic of Central Asian agricultural systems

Quick Exercise Classify the following systems as mainly irrigated, rainfed, pastoral or mountain agriculture:

1. Cotton fields in a lowland river basin.
2. Wheat fields depending mostly on seasonal rainfall.
3. Seasonal sheep grazing in upland pastures.
4. Fruit orchards in a mountain valley.

Then identify one climate risk for each system

7. CLIMATE IMPACTS ON CROPS, WATER AND SOILS

Climate change affects agriculture through several connected mechanisms. It is useful to analyse these mechanisms separately, although in practice they often occur together.

For example, a hotter summer may increase crop water demand, reduce river water availability, increase soil salinity, reduce yields and increase farmer debt. A drought may reduce pasture growth, force livestock sales and increase pressure on remaining grazing areas.

7.1. Heat stress and crop development

Crops develop through stages: germination, vegetative growth, flowering, grain filling or fruit development, and maturation. Each stage has different temperature sensitivity.

Heat stress can:

- Reduce germination.
- Accelerate crop development.
- Shorten grain filling.
- Reduce fruit set.
- Increase water demand.
- Reduce photosynthesis.
- Increase crop respiration.
- Lower yield and quality.

The timing of heat stress is critical. Wheat, for example, may be especially vulnerable during flowering and grain filling. Fruits and vegetables may suffer from quality losses, sunburn, reduced shelf life or increased water demand.

Heat also affects farm labour. Working outdoors under high temperatures reduces productivity and increases health risks.

7.2. Drought and soil moisture deficit

Drought occurs when water availability is below what ecosystems, crops or people need. Agricultural drought is closely linked to soil moisture deficit.

Drought affects agriculture by:

- Reducing crop growth.
- Reducing pasture biomass.
- Lowering groundwater recharge.
- Increasing irrigation demand.
- Increasing crop failure risk.
- Reducing fodder availability.
- Increasing livestock mortality in severe cases.
- Increasing erosion risk when vegetation cover declines.

In semi-arid regions, drought is not exceptional; it is part of the climate system. The challenge is that climate change may increase drought intensity, frequency or duration.

7.3. Irrigation water scarcity

Irrigation water scarcity is a central issue in Central Asia. Agriculture depends heavily on rivers, reservoirs, canals, groundwater and seasonal snowmelt.

Water scarcity may result from:

- Reduced snowpack.
- Earlier snowmelt.
- Glacier retreat.
- Drought.
- Higher evapotranspiration.

- Reservoir management conflicts.
- Canal losses.
- Competing water demands.
- Weak water allocation systems.

When irrigation water is insufficient, farmers may reduce planted area, shift crops, pump groundwater, reuse drainage water or accept lower yields. Some of these responses may create new problems. For example, groundwater pumping may lower aquifer levels, and reuse of drainage water may increase salinity.

7.4. Soil salinity and land degradation

Salinity is one of the most serious land degradation problems in irrigated semi-arid agriculture. Salts may accumulate when irrigation water contains dissolved salts, evaporation is high and drainage is poor.

Climate change can worsen salinity through:

- Higher evaporation.
- Increased irrigation demand.
- Lower dilution in rivers and canals.
- More frequent water shortages.
- Greater reliance on saline drainage or groundwater.
- Reduced flushing of salts from soils.

Salinity reduces crop growth, damages soil structure, lowers yields and can make land economically unproductive. It also affects rural livelihoods because farmers may lose income while still facing irrigation, fertiliser and labour costs.

7.5. Pests, diseases and weeds

Climate change can alter pest, disease and weed pressure. Warmer temperatures may allow some pests to survive winter, reproduce faster or expand into new regions. Changes in humidity and rainfall may influence fungal diseases. Drought-stressed crops may become more vulnerable.

Farmers may respond by increasing pesticide use. This can increase production costs and create risks for soil, water and human health if not managed properly.

WARNING Adaptation measures can create new environmental problems if they are not well designed. For example, increasing irrigation to protect crops from heat may worsen water scarcity or salinity. Expanding pesticide use to control climate-driven pests may increase soil and groundwater pollution.

8. RURAL LIVELIHOODS AND VULNERABILITY

Agriculture is not only a technical sector. It is also the basis of rural livelihoods. Climate impacts on agriculture therefore become social and economic impacts.

A rural household may depend on crops, livestock, wage labour, remittances, kitchen gardens, orchards, pasture access and local markets. Climate change can affect all these income and food sources.

8.1. Farmers and household income

Farmers are vulnerable when climate shocks reduce yields, increase input costs or reduce market access. A drought may reduce production, but the farmer may still have paid for seed, fertiliser, fuel, irrigation and labour.

Climate risks can also affect credit. If farmers borrow money for inputs and then lose the harvest, they may become indebted. Repeated shocks reduce the ability to invest in adaptation.

Small farmers are often more vulnerable because they have less savings, less insurance, less access to technology and less influence over water allocation.

8.2. Pastoralists and livestock systems

Pastoralists depend on pasture, water, animal health and mobility. Climate shocks can reduce pasture growth and force herders to buy fodder, move animals longer distances or sell livestock at low prices.

Extreme winter events, droughts and heatwaves can damage livestock systems. When animals are weakened by poor forage, they become more vulnerable to disease and cold.

Pastoral vulnerability is not only climatic. It is also shaped by land tenure, access to pastures, veterinary services, market access, traditional institutions and local governance.

8.3. Gender, youth and vulnerable groups

Climate change affects rural groups differently. Women, youth, elderly people, landless households and low-income families may have fewer resources to adapt.

Women often play important roles in food preparation, household water management, small livestock, gardens and family nutrition. When water becomes scarce or food prices rise, their workload may increase.

Youth may face limited opportunities in rural areas, especially if agricultural income becomes unstable. Climate stress can therefore contribute to migration or abandonment of rural livelihoods.

8.4. Migration and livelihood diversification

Migration is one way households respond to rural stress. It can provide income through remittances, but it can also reduce local labour availability and affect community structures.

Livelihood diversification can increase resilience. Households with multiple income sources may be better able to cope with climate shocks. Diversification may include processing agricultural products, rural tourism, local services, non-farm employment, beekeeping, greenhouse production or value-added food products.

However, diversification requires skills, finance, markets and infrastructure.



Imagine two households in the same village. One depends only on irrigated wheat. The other combines wheat, vegetables, small livestock and remittances. Which household is more resilient to drought? Why?

9. CLIMATE-SMART AGRICULTURE AND SLM RESPONSES

Climate-smart agriculture is an approach that aims to increase productivity, strengthen adaptation and reduce greenhouse gas emissions where possible. It is closely connected with Sustainable Land Management because both approaches focus on long-term land productivity, soil health, water efficiency and ecosystem resilience.

In Central Asia, climate-smart agriculture must be realistic. It should consider farmer constraints, water availability, institutional capacity, market access and local knowledge.

9.1. Improved water management

Water management is one of the most important adaptation areas.

Useful measures include:

- Irrigation scheduling based on crop needs.
- Canal maintenance.
- Reduction of conveyance losses.
- Field levelling.
- Drip or sprinkler irrigation where feasible.
- Soil moisture monitoring.
- Water user associations.
- Drainage rehabilitation.
- Reuse of water only when salinity is controlled.
- Crop choice adapted to water availability.

Improved water management can reduce drought risk, salinity, energy use and conflicts between users.

9.2. Soil conservation and organic matter management

Soil conservation increases resilience because healthy soils retain more water, resist erosion and support crop growth.

Relevant practices include:

- Reduced tillage.
- Residue retention.
- Cover crops where feasible.
- Mulching.
- Contour farming on slopes.
- Terracing in mountain areas.
- Compost and manure management.
- Windbreaks.
- Avoiding residue burning.
- Preventing soil compaction.

Increasing soil organic matter is particularly important in drylands because it improves water retention and nutrient cycling.

9.3. Crop diversification and resilient varieties

Crop diversification reduces dependence on a single crop and spreads risk. It may include:

- Drought-tolerant varieties.
- Heat-tolerant varieties.
- Short-cycle crops.
- Crop rotations.
- Legumes.
- Forage crops.
- Fruit and vegetable diversification.
- Salt-tolerant crops in affected areas.
- Mixed farming systems.

Diversification must be linked to markets. A crop may be agronomically suitable but economically unrealistic if there is no market, storage or processing capacity.

9.4. Sustainable grazing and pasture restoration

For rangelands, adaptation requires both ecological and institutional measures. Possible actions include:

- Rotational grazing.
- Seasonal pasture planning.
- Adjusting stocking rates.
- Resting degraded pastures.
- Reseeding or assisted regeneration.
- Protecting water points from degradation.
- Improving veterinary services.
- Fodder storage for drought periods.
- Community pasture management.
- Monitoring pasture condition.

Restored pastures can increase forage availability, reduce erosion and store more carbon in roots and soils.

9.5. Agroforestry, shelterbelts and landscape restoration

Agroforestry and shelterbelts can reduce wind speed, protect soils, improve microclimates and store carbon. In drylands, shelterbelts can reduce wind erosion and protect crops from dust.

Landscape restoration may include degraded slopes, riparian zones, saline lands, abandoned fields or rangelands. Restoration should use locally adapted species and consider water availability.

Table 2. Climate-smart agriculture and SLM measures.

Climate risk	SLM / CSA response	Main benefit	Possible limitation
Drought	Soil moisture conservation	Reduces crop water stress	Needs farmer training
Heat stress	Heat-tolerant varieties	Protects yields	Seed access required
Water scarcity	Irrigation scheduling	Reduces water waste	Requires coordination
Salinity	Drainage and salinity monitoring	Protects soil productivity	Infrastructure cost
Pasture degradation	Rotational grazing	Restores vegetation	Requires local agreements
Wind erosion	Shelterbelts	Reduces dust and soil loss	Needs maintenance



Choose one farm type: irrigated cotton farm, rainfed wheat farm, mountain orchard or pastoral household. Select three climate risks and propose one practical adaptation measure for each risk.

10. FROM FARM PRACTICES TO POLICY SUPPORT

Farmers cannot adapt alone. Many adaptation measures require information, finance, infrastructure, institutions and public support.

For example, a farmer may understand that drip irrigation saves water, but may not afford the investment. A pastoralist may know that pasture needs rest, but may lack access to alternative grazing areas. A community may need drainage maintenance, but responsibility may be unclear.

This is why climate adaptation in agriculture requires both field-level practices and institutional support.

10.1. Extension services and farmer training

Extension services help translate scientific and technical knowledge into practical advice. They can support farmers in:

- Irrigation scheduling.
- Fertiliser management.
- Soil testing.
- Pest management.
- Salinity monitoring.
- Crop selection.
- Pasture planning.
- Drought preparedness.
- Use of climate information.
- Record keeping and farm planning.

Effective extension must be practical, locally relevant and trusted by farmers.

10.2. Climate information and early warning

Climate information helps farmers make decisions before damage occurs. Useful information includes:

- Seasonal forecasts.
- Drought warnings.
- Frost warnings.
- Heatwave alerts.
- River flow forecasts.
- Soil moisture information.
- Pest and disease warnings.
- Reservoir and irrigation supply information.

Early warning is useful only if farmers and institutions can act on it. Information must be understandable, timely and linked to response options.

10.3. Incentives, insurance and finance

Many adaptation practices require investment. Public support may include:

- Subsidies for efficient irrigation.
- Grants for soil conservation.
- Credit for climate-resilient technologies.
- Insurance schemes.
- Support for drought-tolerant seeds.
- Payment for ecosystem services.
- Funding for pasture restoration.
- Support for drainage rehabilitation.
- Public investment in monitoring systems.

Financial instruments must avoid creating maladaptation. For example, subsidies should not encourage expansion of water-intensive crops in water-scarce basins.

10.4. Local institutions and water user associations

Local institutions are essential because agricultural adaptation is place-specific. Water user associations, pasture committees, farmer cooperatives and municipalities can coordinate actions that individual farmers cannot solve alone.

Examples include:

- Canal maintenance.
- Water allocation.
- Pasture rotation.
- Shared machinery.
- Local storage.
- Collective marketing.
- Monitoring of wells and salinity.
- Conflict resolution.

Strong local institutions increase the effectiveness of technical measures.

WARNING A technically correct adaptation measure may fail if it ignores farmer constraints. Cost, labour, land tenure, market access, water rights, tradition and trust in institutions determine whether farmers can actually adopt new practices.

11. MONITORING AGRICULTURAL CLIMATE RESILIENCE

Monitoring helps determine whether agricultural systems are becoming more resilient or more vulnerable. It also helps governments and development programmes decide where to invest.

Monitoring should combine biophysical indicators with social and economic indicators. Crop yield alone is not enough. A farm may maintain yield by using more water, more fertiliser or more debt, which may not be sustainable.

11.1. Field indicators

Field indicators include:

- Crop yield.
- Soil moisture.
- Soil organic matter.
- Soil salinity.
- Groundwater depth.
- Irrigation water use.
- Fertiliser use efficiency.
- Crop diversity.
- Pasture biomass.
- Vegetation cover.
- Erosion signs.
- Livestock body condition.
- Fodder availability.

These indicators can be collected by farmers, extension agents, researchers or local authorities.

11.2. Remote sensing indicators

Remote sensing is useful for monitoring large agricultural and rangeland areas.

Useful indicators include:

- NDVI or vegetation greenness.
- Land surface temperature.
- Soil moisture products.
- Evapotranspiration estimates.
- Crop area mapping.
- Drought indices.
- Snow cover.
- Burn scars.
- Land degradation trends.

Remote sensing should be validated with field data. Satellite images can show where vegetation is stressed, but local knowledge is needed to explain why.

11.3. Livelihood and food-security indicators

Social and livelihood indicators are also needed.

Examples include:

- Household income diversity.
- Food expenditure.
- Livestock numbers.
- Migration patterns.
- Access to irrigation water.
- Access to extension services.
- Use of climate information.
- Farm debt.
- Market access.
- Women's workload.

- Youth employment.
- Dietary diversity.

Climate resilience is not only the ability of crops to survive drought. It is also the ability of rural households to maintain food, income, dignity and future options.

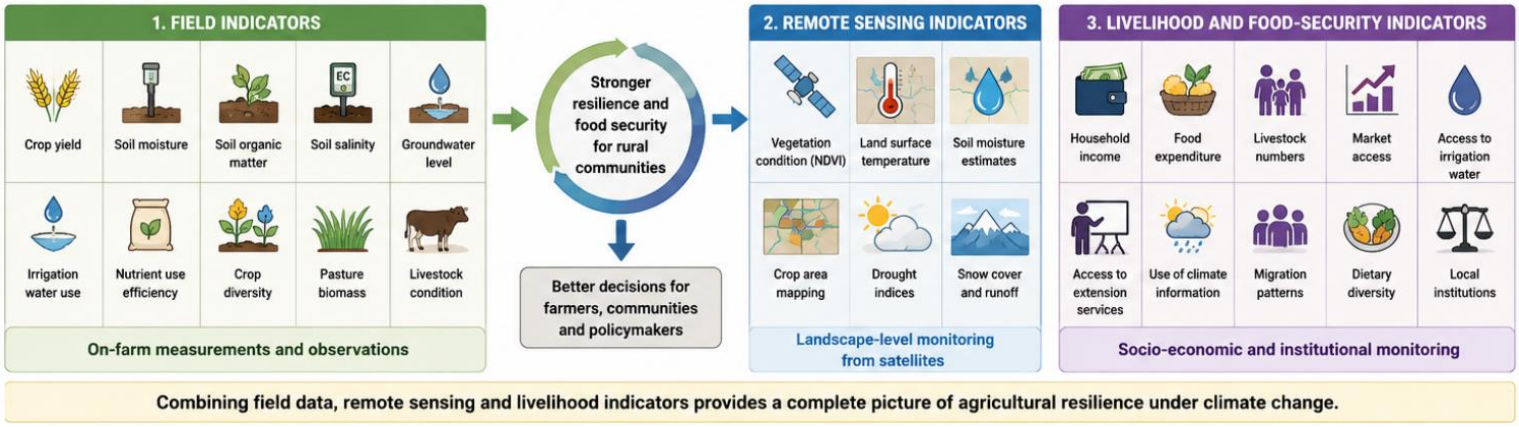


Figure 3. Agricultural climate resilience monitoring framework showing three groups of indicators

Did you know..? Satellite data can detect vegetation stress over large areas, but they cannot explain farmer decisions, household income or local water conflicts. For agricultural resilience, remote sensing and field interviews should be used together.

12. CONCLUSIONS

Climate change is reshaping agricultural systems in Central Asia through rising temperatures, changing water availability, more frequent droughts, glacier and snowmelt changes, soil salinity, pest pressures and extreme events. These impacts affect crops, livestock, soils, irrigation systems and rural livelihoods.

Food security must be understood through availability, access, utilisation and stability. Climate change can affect all four pillars, not only through reduced crop production but also through income loss, price changes, nutrition risks and repeated shocks.

Central Asia's agricultural systems are diverse, and each has specific vulnerabilities. Irrigated agriculture faces water scarcity and salinity. Rainfed agriculture faces rainfall variability and drought. Pastoral systems

face pasture degradation, water shortages and heat stress. Mountain agriculture faces erosion, short growing seasons and changing snow and glacier dynamics.

Sustainable Land Management and climate-smart agriculture provide practical tools for adaptation. Improved irrigation, soil conservation, crop diversification, sustainable grazing, shelterbelts, restoration and better nutrient management can reduce vulnerability and support long-term productivity.

However, adaptation is not only a technical matter. Farmers need access to knowledge, finance, institutions, climate information, markets and supportive policies. Measures must be realistic under local constraints. A successful adaptation strategy must combine field-level practices with governance, monitoring and rural development support.

The central message of this lesson is that climate-resilient agriculture is essential for Sustainable Land Management in Central Asia. Protecting soils, water, crops, pastures and rural livelihoods is not only an environmental objective; it is a foundation for food security, social stability and long-term regional resilience.

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