BRICS COMPETITION LAW&POLICY CENTRE
International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at
TALAP
United Nations Convention to Combat Desertification

Draft undergoing technical adjustments.

Carbon Farming in Kazakhstan: Unlocking the Opportunity

Supported by the Government of the Republic of Kazakhstan

2023

BRICS COMPETITION LAW&POLICY CENTRE
International Institute for Applied Systems Analysis IIASA www.iiasa.ac.at
TALAP
United Nations Convention to Combat Desertification

Carbon Farming in Kazakhstan: Unlocking the Opportunity

Supported by the Government of the Republic of Kazakhstan

2023

Authorship

Lead authors:

Michael Obersteiner, Director, Environmental Change Institute, University of Oxford; Principal Research Scholar, International Institute for Applied Systems Analysis (IIASA)

Alexey Ivanov, Director, BRICS Competition Law and Policy Centre

Elena Rovenskaya, Program Director, Advancing Systems Analysis Program, International Institute for Applied Systems Analysis (IIASA)

Chapter authors:

Yury Rovnov, Senior Research Fellow, BRICS Competition Law and Policy Centre

Sarah Hathiari, Researcher, International Institute for Applied Systems Analysis (IIASA)

Contributing authors (listed in the alphabetic order):

Olga Andreeva, Programme Officer, Science Technology and Innovation, United Nations Convention to Combat Desertification (UNCCD)

Jeroen van Dalen, Programme Officer, Partnerships, United Nations Convention to Combat Desertification (UNCCD)

Alexander Golub, Adjunct Professor, Department of Environmental Science, American University

Radhika Jain, Associate Programme Officer, Innovative Financing, United Nations Convention to Combat Desertification (UNCCD)

Xiaoxia Jia, Programme Officer, Science, Technology and Innovation Unit, United Nations Convention to Combat Desertification (UNCCD)

Johns Muleso Kharika, Chief of Science, Innovation and Technology Unit, United Nations Convention to Combat Desertification (UNCCD)

Tatenda Lemann, WOCAT Executive Team Member and Senior Research Scientist at the Centre for Development and Environment (CDE), University of Bern

Aleksandre Martusevich, Guest Senior Research Scholar, International Institute for Applied Systems Analysis (IIASA)

Eleanor Milne, WOCAT Associated Researcher

Pradeep Monga, Senior Advisor and Emeritus Research Scholar, International Institute for Applied Systems Analysis (IIASA); Former Deputy Executive Secretary, United Nations Convention to Combat Desertification (UNCCD)

Barron Joseph Orr, Chief Scientist, United Nations Convention to Combat Desertification (UNCCD)

Rakhim Oshakbayev, Director, TALAP Center for Applied Research

Institutions involved in the production of this report

International Institute of Applied Systems Analysis (IIASA)

IIASA is an international scientific institute that conducts policy-oriented research into global challenges arising from economic and technological development facing the twenty-first century such as climate change, natural resources management, or inequality. IIASA was established in 1972 by a joint initiative of the United States of America and the Soviet Union. Currently IIASA is supported by 21 national and regional member which represent over 60% of the global population and almost 70% of the global economy. A significant proportion of IIASA's research explores nature-positive solutions striving for economically viable environmentally- and socially positive solutions which bring in multifaceted development and international commendations. Over the years, IIASA has developed a rich and meaningful relationship with researchers, diplomats, and policymakers across Central Asia.

BRICS Competition Law and Policy Centre

The BRICS Competition Law and Policy Centre was established in 2018 by the BRICS competition authorities. The Centre's work is aimed at collecting and analyzing information from competition agencies, identifying best practices, but primarily at preparing recommendations and developing approaches to competition policy that reflect development interests of the BRICS economies. The key mission of the BRICS Competition Centre is to advance the development agenda and strengthen the role of competition regulation in overcoming imbalances in the global economy. The Centre brings together leading international universities and independent researchers who are actively involved in the Centre's main research projects: on global food chains, on sustainability policy and on new approaches to antitrust regulation of the digital economy.

United Nations Convention to Combat Desertification (UNCCD)

UNCCD is the global vision and voice for land. The UNCCD unites governments, scientists, policymakers, private sector and communities around a shared vision and global action to restore and manage the world's land for the sustainability of humanity and the planet. Much more than an international treaty signed by 197 parties, UNCCD is a multilateral commitment to mitigating today's impacts of land degradation and advancing tomorrow's land stewardship to provide food, water, shelter, and economic opportunity to all people in an equitable and inclusive manner.

TALAP Research Center

TALAP is a non-governmental think tank created to promote sustainable development of the Republic of Kazakhstan. The UN Sustainable Development Goals, a comprehensive and methodologically elaborated set of goals, objectives and indicators to improve the quality of life of citizens, socio-economic development and environmental protection, are the ideological framework for TALAP's civic activities.

World Overview of Conservation Approaches and Technologies (WOCAT)

WOCAT is a global network on Sustainable Land Management (SLM) that promotes the documentation, sharing and use of knowledge to support adaptation, innovation, and decision-making in SLM. Nestled within WOCAT's continuously expanding and standardized SLM repository, a compendium of over 2300 SLM practices spans across the global landscape, encompassing more than 250 contributions from Central Asia.

Table of Contents

List of Acronyms

ADB	Asian Dryland Belt
AFOLU	Agriculture, Forestry, and Other Land Use
AI	Aridity Index
AR	Afforestation and Reforestation
ART	Architecture for REDD+ Transactions
BAU	Business-as-usual
BECCS	Bioenergy with Carbon Capture and Storage
BRICS	Brazil, Russia, India, China, South Africa
BVCM	Beyond Value Chain Mitigation
CAD	Canadian Dollar
CBAM	Carbon Border Adjustment Mechanism
CBB	Carbon Backed Bonds
CCER	Chinese Certified Emissions Reduction
CCM	Compliance Carbon Market
CCS	Carbon Capture and Storage
CDM	Carbon Development Mechanism
CDR	Carbon Dioxide Removal
CER	Carbon Emissions Reductions
CIF	Climate Investment Funds
CO_2	Carbon Dioxide
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CSR	Corporate Social Responsibility
CTF	California Tropical Forest Standard
DAC	Direct Air Capture
EEWA	Eastern Europe and Western Asia region
ETS	Emissions Trading Scheme
EU	European Union
EUA	European Union Allowances
EUR	Euro
EW	Enhanced weathering
FAO	Food and Agriculture Organization of the United Nations
GB£	Great Britain Pounds
GDP	Gross Development Product
GHG	Greenhouse Gas
GPP	Gross Primary Production
GtCO2(e)	Gigaton of carbon dioxide (equivalent)
GWP	Global Warming Potential
ICAP	International Carbon Action Partnership
ILUC	Indirect Land Use Change
IPCC	Intergovernmental Panel on Climate Change
JNR	Jurisdictional and Nested REDD+ Framework by VERRA
JREDD	Jurisdictional REDD+
KAZ ETS	Kazakhstan ETS
KZT	Kazakhstan Tenge
LDN	Land Degradation Neutrality
LEDS 2060	Low Emissions Development Strategy 2060
LUC	Land Use Change
LULUCF	Land use, land-use change, and forestry
MRV	Measuring, Reporting, Verification
MtCO2(e)	Million tons of carbon dioxide (or equivalent)
MW	Megawatt
NBS	Nature Based Solutions

NDC	Nationally Determined Contributions
NET	Negative Emission Technologies
NGO	Non-governmental Organization
NZ ETS	New Zealand Emissions Trading Scheme
OECD	Organisation for Economic Co-operation and Development
OTC	Over the counter
RBP	Results-Based Payment
REDD/ REDD+	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (+ additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks)
RGGI	US Regional Greenhouse Gas Initiative
SCS	Soil Carbon Sequestration
SDG	Sustainable Development Goals by the United Nations
SEP	US Soil Enrichment Protocol
SGD	Singapore Dollar
SLB	Sustainable Land Bond
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
tCO2/e	Ton of Carbon Dioxide/equivalent
TREES	The REDD+ Environmental Excellence Standard by ART
UK	United Kingdom
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
US$	United States Dollar
USDA	United States Department of Agriculture
VCM	Voluntary Carbon Market
VCS	Verified Carbon Standard

Foreword

Yerlan Nyssanbayev

Minister of Ecology and Natural Resources of the Republic of Kazakhstan

This is a very timely report which zooms in on the potential of land-based mitigation activities for climate action in Kazakhstan and, more broadly, on Central Asian drylands. It elaborates on Kazakhstan's commitment to the adoption of sustainable land management practices as a matter of priority as part of our country's Strategy to Achieve Carbon Neutrality by 2060. As the report demonstrates, in addition to their climate mitigation effect, carbon sequestration activities in agriculture may provide a range of co-benefits to farmers and land users, including improvements in soil health and functions as well as securing extra income through the participation in regional and international carbon markets.

The climate challenge requires a collective response from the world community. Kazakhstan is a strong supporter of close international cooperation in climate action. In this regard, President Tokayev has proposed setting up the Project Office for Central Asia on Climate Change and Green Energy in Almaty and hosting a Regional Climate Summit in Kazakhstan in 2026 under the UN auspices. Due to their multiple and varied positive effects, land-based climate mitigation solutions merit special focus in Kazakhstan's efforts to promote climate cooperation in the region and internationally.

I commend this report as a valuable contribution to a broader and better awareness of policy makers and the general public about the benefits of carbon farming activities as a sustainable land management and climate solution.

Executive Summary

This report discusses how carbon farming and trading can provide a marked contribution to Kazakhstan's socio-economic development while making it more resilient to climate change and supporting the country's commitment to combat environmental degradation and climate change. It explores viable options for leveraging the potential of sustainable land management (SLM) to support Kazakhstan's net-zero transition and land restoration and, more than that, to enable the country's accelerated economic development and modernization ambitions.

The most recent Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) concludes that there is an 'unequivocal' causal link between greenhouse gas (GHG) emissions from human activities and global warming observed since mid-19th century. The increase in the world population and the concomitant rise in demand for energy, generated foremost using fossil fuels, to sustain economic growth mean the pace of abatement of GHG emissions may fall short of what is necessary to contain global warming within the 1.5–2°C threshold established by the Paris Agreement. In particular, the countries' emission reduction plans expressed in their 'nationally determined contributions' (NDCs) submitted under the Paris Agreement are largely insufficient to prevent transgression of the 2°C limit and are estimated to result in the global mean surface temperature increasing by 2.1–2.9°C by the end of the century (and keeping rising thereafter).[1]

The effects of climate change are already felt worldwide and will become more pronounced as warming progresses. The IPCC AR6 points to 'widespread, pervasive impacts [of climate change on] ecosystems, people, settlements, and infrastructure', including 'increased heat-related human mortality, … increased drought-related tree mortality, … increasingly irreversible losses in terrestrial, freshwater and coastal and open ocean marine ecosystems'. Climate change has caused '[h]undreds of local losses of species … driven by increases in the magnitude of heat extremes …, as well as mass mortality events on land and in the ocean'.[2]

Kazakhstan is not immune to the adverse impacts of climate change. With most of the country's territory located in arid and semi-arid climate zones, the development of its agriculture in several regions has been shaped by acute water scarcity exacerbated by competition with mining and, if not managed well, hydropower generation for limited water resources. Large-scale development projects of the second half of the 20th century, such as the Virgin Lands campaign in the north of the country and the diversion of vast amounts of water for irrigation and power generation in the south, took their toll on the fragile landscapes by depleting their biological resources and reducing the agricultural quality of soils. According to the latest Kazakhstan estimates,[3] about 21%, or 57Mha, of Kazakhstan's total land area have been degraded,[4] including 27 Mha of rangelands.[5]

Climate change is projected to place an additional burden on these lands and further reduce crop and forage yields. By 2050, increasing mean temperatures and changing precipitation patterns may see the yields of wheat, Kazakhstan's main staple crop and export product, decrease by over a quarter[6] and forage productivity of mountain rangelands shrink by up to 42% by 2050.[5] Harvests will be additionally threatened by higher frequencies of disease and pest (in particular, locust) outbreaks as well as an expansion of affected areas. Kazakhstan being a major grain exporter, these developments are bound to have ramifications for regional and global food security and the country's domestic economy.

The urban infrastructure, including roads, power grids, cell phone towers, and water supply systems, may be severely impacted by droughts exacerbated by prolonged heatwaves, especially in western Kazakhstan.

Climate-related disasters in the Middle East and Central Asia have already been causing 2,600 extra deaths in an average year, as well as leading to injuries to and displacement of 7 million people and resulting in physical damage of around US$ 2 billion[7]. In mountainous regions, including southern Kazakhstan, Zhambyl, and Almaty, flood and mudslide risks have soared to 4.7 times the 1991 levels. Riverine flooding in Almaty oblast increased by 35% between 1991 and 2015[8].

Decarbonization is indispensable to containing climate warming and preventing exacerbation of its adverse effects beyond 'tipping points', i.e., thresholds whose crossing may result in critical and irreversible damages to the climate system. Decarbonization includes the reduction of current emissions worldwide, but also the removal of carbon dioxide (CO_2) to compensate for residual emissions.[9] Carbon dioxide removed from the atmosphere has to be durably stored in another high-capacity reservoir, such as the ocean, land, or geological formations (e.g., depleted gas reservoirs).

Furthermore, as global decarbonization gathers pace, Kazakhstan's economy faces significant transition risks including risks related to rising financing costs, and the climate policies of other countries (such as trade restrictions on carbon-intensive activities). According to estimates of the World Bank, 'the European Union's Carbon Border Adjustment Mechanism (CBAM) could cost Kazakhstan US$ 250 million in export receipts annually from iron and steel, and up to US$ 1.5 billion if the scope of CBAM is expanded to include crude oil'.[10]

For Kazakhstan, leveraging land-based carbon sequestration appears a very promising strategy to enhance decarbonization through carbon removal. Indeed, lands (which are understood to consist of soils, vegetation, and other biota, among other things) are estimated to absorb around a third of annual anthropogenic emissions[11] and to store 2.5 times as much carbon as the atmosphere globally.[12] The storage capacity of soils is 2.5 times that of plant biomass,[12] and grasslands have been found to be more effective at putting carbon back into soils than forests at elevated CO_2 levels.[13] Compared to industrial removal activities, such as direct air carbon capture and storage in geological formations, biological, and in particular land-based solutions, are more technologically mature, involve significantly lower costs, and are already being implemented at scale.[14] As concluded by the Supervisory Body for Article 6.4 of the Paris Agreement, land-based carbon removal activities 'are proven and safe, have a long history of practice, … are backed by considerable experience under compliance and voluntary carbon market mechanisms' and 'have the potential to deliver cost-effective CO_2 mitigation required by 2030…'.[15]

To incentivize cost-effective decarbonization, a number of states have resorted to cap-and-trade systems in which overachieving installations subject to a statutory GHG emission cap can sell excess emission allowances to underachieving installations facing a shortage of emission allowances. Emission trading under cap-and-trade schemes is conducted on what is known as 'compliance carbon markets (CCMs)'. International trade in emission units between countries was also an element of the Kyoto Protocol which established emission caps for some of its parties. In parallel, VCM (VCMs) have been developing worldwide, on which carbon credits from climate mitigation projects (i.e., a quantified equivalent of emissions removed or reduced through project activities) are sold to buyers who are not subject to a statutory emission cap but wish to 'offset' their carbon footprint for other reasons, such as the reporting requirements of an exchange on which their securities are traded or the public image purposes. The current size of the VCMs is estimated at US$ 2 billion globally with positive projections for growth in both demand and supply over the coming decades.[16]

International trade in carbon credits generated by climate change mitigation projects is an essential element of both the Kyoto Protocol and the Paris Agreement and is aimed at promoting a cost-effective and cooperative approach to climate mitigation. Nearly 1.5 billion certified emission reductions (CERs) were issued in the first commitment period of the Kyoto Protocol (2008 to 2012) as part of its Clean Development Mechanism (CDM) and in excess of 0.8 billion emission reduction units (ERUs) under Joint Implementation projects. Developing countries and economies in transition, including China, India, Brazil and Russia, accounted for the bulk of the credits issued.[17]

Azerbaijan, Uzbekistan, and, more recently, Kazakhstan have signed bilateral agreements with Japan under Article 6.2 of the Paris Agreement. The Supervisory Body for the Article 6.4 mechanism is currently developing detailed rules and modalities for applying the trading mechanism between private parties under Article 6.4 which should set up a significant international market for land-based carbon credits.

Land-based activities thus carry the double potential as both a climate change mitigation tool and a generator of carbon credits that can be traded domestically and internationally. In this context, a number of countries have launched their own carbon crediting mechanisms. For instance, in Australia, carbon credits under the Australian Carbon Credit Unit Scheme can be earned for land-based projects such as savanna fire management.[18,19] In the UK, the Woodland Carbon Code standard was launched in 2011, which generates verified carbon units for woodland restoration projects.[20] China is preparing to relaunch the China Certified Emission Reduction (CCER) scheme, which is expected to reach US$ 2.8 billion in turnover by 2025.

In Kazakhstan, vast areas of steppes and semi-deserts may be transformed into high-capacity carbon sinks. Degraded soils in arid and semi-arid climatic zones offer large carbon sequestration potential, which may exceed that of forest-based ecosystems. This may be especially true of the ‘Virgin Lands’ areas that were intensively developed in the second half of the 20th century to expand crop production and are estimated to have lost up to 45% of their soil carbon stock in the process. While croplands that remain croplands continue losing carbon, abandoned croplands reportedly sequestered more than 1.8 tCO2/ha from the mid-1990s to 2010.[11] The loss of the soil organic carbon (SOC) is directly associated with and is a major attribute of soil degradation. Carbon sequestration by degraded lands therefore not only removes excess carbon dioxide from the atmosphere but also helps to build climate resilience by improving soil properties, reducing nutrient leaching, enhancing water infiltration, and potentially increasing yields—even with less fertilization, among other effects.

There exists a range of land management practices which can result in carbon sequestration by soils and plant biomass and/or in reduction of GHG emissions. Such nature-based solutions may come under different names in different contexts. SLM is the term of trade for the United Nations Convention to Combat Desertification (UNCCD).[22] The Food and Agriculture Organization of the United Nations (FAO) refers to some SLM practices as ‘conservation agriculture’[23] while the World Bank uses the term ‘climate-smart agriculture’ in its country climate and development reports. The notions of ‘regenerative agriculture’ and ‘organic farming’ are also broadly employed.

This report uses the term ‘carbon farming’ to refer to land management practices at the farm level which either increase the amount of atmospheric carbon sequestered (i.e., captured and stored) by soils and plant biomass or reduce GHG emissions from activities in the Agriculture, Forestry, and Other Land Use (AFOLU) sector. While one or more of the terms mentioned above can also be used in relation to some of the same practices, ‘carbon farming’ emphasizes their carbon sequestration or emission mitigation purpose and potential.

Understood more broadly, carbon farming may also refer to the management of livestock as well as land at farm level[24] and hence may involve, for instance, measures to reduce methane emissions from enteric fermentation in ruminants. The notion of carbon farming may apply also to aquaculture.[25] This publication however focuses specifically on land management practices. Examples include no-till or reduced tillage intensity, residue retention, crop rotation, cover cropping, improved grass varieties, and deep-rooting grasses.

Facing severe land degradation, Kazakhstan has emerged as a leader in promoting conservation agriculture in Central Asia and one of the top adopters globally[26] with 3 Mha converted to conservation farming as of 2018—not least thanks to government subsidies which have been facilitating the adoption of conservation agriculture practices since 2008.[27] Gradual improvement in natural vegetation cover and land productivity in some regions has been reported, especially in the pasture areas as a result of extensive restoration projects, irrigation upgrades, and abundant land reclamation. A Global Environment Facility (GEF)-funded landscape restoration project was launched in 2021, which will pilot community-centered afforestation with saxaul trees in the dried-out Aral sea bottom and establish nine agroforestry demonstration plots, among other activities.[28] Bottom-up initiatives to develop carbon farming have begun to surface.[29]

Despite these commendable efforts, SLM practices are currently applied on as little as 1% of Kazakhstan's agricultural lands[30] and its Land Use, Land Use Change and Forestry (LULUCF) sector remains a source of emissions rather than a sink.[5] Kazakhstan's most recent National Communication to the UNFCCC recognizes that a 'very large' potential for mitigation exists on its croplands, in the order of 35 Mt CO_2-equivalent per year.[5] Conceivably, an even higher potential is waiting to be tapped on the vast expanses of its abandoned arable lands and overgrazed rangelands. With proper incentives in place, the adoption of carbon farming on these lands may generate significant environmental, economic, and social benefits.

A portfolio of support measures including fiscal ones such as agricultural subsidies will be crucial in setting up an effective framework for carbon farming in Kazakhstan. The involvement of the government is key to making it work. Public funding of carbon farming schemes provides the required stability to the arrangement,[24] especially at the initial stage. Payments can be made for practices adopted (action-based scheme) or for actual sequestration/mitigation achieved (result-based scheme).[24] International investment opportunities for nature-based solutions (NBS) including green bonds, LDN funds, or concessional loans merit separate consideration as they could prove useful not only for financing early programs but also as opportunities for knowledge and technology spillovers. Trading in carbon offset credits generated from land-based climate mitigation solutions may be among the main pillars of the financial incentives scheme. This will allow project owners to sell certified carbon credits to entities and individuals to offset their own unabated emissions in order to meet their self-defined emission reduction targets. According to estimates, carbon prices in compliance markets must reach at least US$ 50-100/tCO2e by 2030 (in real terms) to sufficiently incentivize decarbonization and limit global warming to 2°C.[31] This level can be thought of as a guidance for carbon offset prices, too.

Implementation costs for carbon farming activities can range depending on the type of carbon farming method implemented. Some estimations can be made based on previous land management practices closely linked with carbon farming methods, for example, in the Katon Karagay region, 80 hectares of land was revitalized through sowing grasses such as sainfoin seeds costing less than US$ 50 per ha including maintenance.[32] Costs of carbon farming activities already implemented in different regions of the world with the aim to sequester carbon have ranged around US$ 10-30/tCO2e in the US (no-till and cover crops) and US$ 16/tCO2e in China (cropland-livestock systems).

As many carbon farming methods necessitate significant upfront investments, the implementation costs per a unit of sequestered carbon can be reduced through the realization of economies of scale. Thus, carbon farming is likely to become economically viable with the ramping-up of decarbonization regulation worldwide.

Kazakhstan already has carbon market infrastructure in place. Within Central Asia, it has been a frontrunner in establishing a functional compliance market, the Kazakhstan Emissions Trading System (KAZ ETS). Kazakhstan's cap-and-trade scheme covers key industries which account for approximately 47% of the country's total carbon emissions. KAZ ETS is also one of the few emissions trading scheme ETS systems in the world which permits regulated entities to use carbon offsetting credits to meet their emission reduction obligations.

However, until now, lenient allocation of carbon allowances has been exerting downward pressure on the price of emissions which remain starkly low with allowances traded below US$ 2 in the domestic secondary market. More stringent allocation of allowances in the domestic compliance market would drive the carbon price up and increase demand for offset credits. This will provide an opportunity for farmers to obtain revenues through domestic trading of carbon credits once carbon farming is integrated into the KAZ ETS.

To be recognized and marketable internationally, carbon offsets generated in Kazakhstan must be supported by a robust monitoring, reporting and verification (MRV) system to give offset purchasers confidence in the quality of the carbon credits they buy. An MRV protocol applied must provide assurance that the offsets reflect actual emission volumes permanently or durably removed or reduced and that these results are additional to what would have been achieved in a baseline scenario without adopting the carbon farming activities. As there is no single MRV protocol for removal and emission reduction activities in the AFOLU sector, it is reasonable to rely on the MRV protocols developed by specialized international bodies, such as, for instance, the FAO protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes,[33] and on the carbon project methodologies currently under review by the Supervisory Body for the Article 6.4 mechanism. The latter are due to become available in the near future and are expected to largely shape the VCM landscape. The MRV protocols applied by the world's largest standards such as Verra or Gold Standard may also serve as useful guidance.

In setting up a trading infrastructure for carbon offset credits, Kazakhstan will need to optimize their channelization CCMs and VCMs on the one hand, and domestic and international markets, on the other, to ensure that farmers are able to maximize their revenues while Kazakhstan as a country meets its national emission targets. Participation in the Article 6.4 mechanism which provides for prior approval of climate project activities by the host government will allow the State to remain in control of the amount of carbon credits that will be sold internationally through the mechanism and will thus not count towards achievement of the country's NDC.

As mentioned above, carbon farming is distinct in that it may provide an array of co-benefits on top of climate mitigation and payments for carbon sequestration. Farmers—especially those working on degraded lands—stand to derive additional financial benefits from improvements in soil functions resulting from soil organic carbon stock replenishment. Changes in SOC content have been found to be directly related to soil health, its nutrient and water content, and, therefore, crop yields, among other things. For this reason, restoring SOC stock to its potential levels positively affects agricultural production and improves fertility such that sustainable commercial farming may also take place in the future. Implementation of carbon farming at scale may have positive ramifications across the value chains of which participating famers are a part and have a significant upside for the rural communities involved.

Carbon farming may also yield substantial economic and social co-benefits at large. Sustainable land management practices have been estimated to create up to 1 job per 1 hectare of land on which they are implemented.[34] In the US, landscape restoration projects have been found to create between 10 and 39 jobs for each US$ 1 million invested — at least twice the return in the oil and gas sector.[35] A UNCCD report estimates that restoring 150 million ha of degraded agricultural land could generate US$ 85 billion for national and local economies and US$ 30 to 40 billion a year in additional income for smallholder farmers.[35]

SLM and ecosystem restoration activities have the capacity to serve new economic development opportunities for farming communities in rural areas which could help reduce the urban-rural disparities of the country. In the long run, the adoption of agroecological approaches that renew habitat and restore ecosystems may allow rural communities to participate in eco-tourism initiatives or access funding for sustainable agriculture projects. Overall, carbon farming has the potential to improve economic welfare in rural regions hindered by land degradation. Revival of such lands unlocks opportunity for new employment and enterprise which could have positive spill-over effects at the local, regional and national scale.

When implemented at scale, carbon farming will produce significant amounts of biomass which will find a variety of applications in a circular bioeconomy. It can be used as feedstock in the production of second-generation biofuels or in BECCS processes which occupy such a prominent place in the current decarbonization scenarios. Potential non-energy applications include the manufacturing of construction materials (e.g., dried reed stalks for the construction of outbuildings), extraction of food or feed proteins, and chemical processes, among others.

Reverting to sustainable carbon cycles, restoring ecosystems and achieving land degradation neutrality should be the guiding principles of a carbon farming program with local communities put at the center of the equation. There is an obvious synergy between restoration of SOC stocks and the achievement of the UN Sustainable Development Goals (SDG), including that of combatting desertification, restoring degraded land and achieving land degradation neutrality (target 15.3 of SDG 15 Climate Action). Kazakhstan has now a unique opportunity to become the trailblazer in the area of carbon farming and provide a role model for other countries in the region and beyond, in other regions of the temperate zones, which can yield valuable political dividends for the country internationally.

***

The full report is organized as follows. After describing the background for the Paris Agreement and the temperature targets established by it, this report discusses the role of CDR technologies, and in particular land-based activities, in containing global warming within the Paris Agreement limits (Chapter 1). In this context, Chapter 2 considers the benefits of applying land based CDRs in the arid and semi-arid climates of the Asian Drylands Belt (ADB) region of which Kazakhstan is part. Chapter 3 zooms in on the potential of carbon farming for Kazakhstan as a climate solution with significant environmental, economic, and social co-benefits.

The next Chapters present the most crucial economic considerations in developing a carbon trading industry in Kazakhstan. Accordingly, Chapter 4 provides an analysis into international carbon markets and the nuances of trading carbon derivatives. This Chapter also delves into the heterogeneity of carbon credits and the impact this has on the eventual price emitters are subject to pay. It also explores observable trends in the demand for carbon credits given international policies such as border adjustment taxes and carbon tariffs on imports. Chapter 5 addresses the key questions on how the Government of Kazakhstan could support the development of a national carbon farming and trading program.

The chapter will deliver key insights into the MRV processes critical to the acceptance of carbon credits, the institutional and fiscal structure needed to support farmer participation, and the international investment mechanisms potentially available to Kazakhstan. Lastly, Chapter 6 concludes the report by evaluating the environmental, social, and economic benefits of initiating carbon farming and trading in Kazakhstan in the context of global targets, including the UN SDGs.

This report intends to provide an initial overview of the opportunities and challenges related to the establishment of carbon farming and trading in Kazakhstan. It has been informed by vast academic literature as well as documented experience of other countries. A detailed exploration of costs, benefits, synergies, and tradeoffs, as well as spatial heterogeneities and temporal dynamics specific to Kazakhstan or another country or region in the ADB area which may wish to develop own carbon farming and trading is required to substantiate a road map towards the implementation of this innovative and ambitious objective.

1. Negative Emissions for Climate Change Mitigation

1.1 The Paris Agreement and Temperature Targets

The increase in the average temperature of the Earth's surface is attributed to the growing concentration of the GHG in the troposphere—the planet's lower atmosphere which extends up to 20 kilometers from the Earth's surface. These gases—primarily carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), but also hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6), among others—withhold the infrared spectrum of solar radiation near the planet's surface thus increasing the Earth's surface temperature. The higher is the GHG concentration, the higher is the temperature on the Earth.

The concentration of CO_2 is estimated to have increased from around 280 to 410 ppm since 1750, that of CH_4—from around 730 to 1866 ppb, that of N_2O—from around 270 to 332 ppb. [36] The effect of different GHGs on the surface temperature is different as they all have different heat trapping potentials and different lifetimes in the atmosphere. For instance, while the heat trapping potential of CH_4 is about 100 times larger than that of CO_2, the former is much more short-lived and breaks down within a couple of decades after being released while a large share of emitted CO_2 may persist for centuries. The global warming potential of CH_4 over a 100-year period (GWP_{100}, a simplified metric commonly used to compare the warming effect of different GHGs) is therefore estimated to be 'only' 28 to 32 times that of CO_2, depending on the approach to modelling; for a shorter timeframe, the difference would accordingly be larger. The GWP_{100} of N_2O is 265 to 298.[37]

There is a broad scientific consensus that human activity, such as the burning of fossil fuels or agricultural production, is a major reason for the rising GHG concentrations and increasing temperature. The most recent Sixth Assessment Report of the IPCC states that '[o]bserved increases in well-mixed [GHG] concentrations since around 1750 are unequivocally caused by human activities'[38] and concludes that '[t]he likely range of total human-caused global surface temperature increase from 1850-1900 to 2010-2019 is 0.8°C to 1.3°C, with a best estimate of 1.07°C,' [38] while the overall global surface temperature increase from 1850-1900 to 2011-2020 is estimated to very likely fall within the 0.95°C to 1.20°C range [38] This temperature rise has resulted in melting Arctic sea ice, rising global mean sea level, more frequent and more intense heat extremes, heavy precipitations, and compound extreme events, among other impacts.[38]

The recognition of the adverse impacts of the human activities on climate led to the adoption of the UNFCCC, which entered into force in 1994 and has 198 participants at the time of writing, including Kazakhstan.[39] Pursuant to Article 2 of the UNFCCC, its ultimate objective is to 'achieve... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' and to do so 'within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.'

This objective was intended to be achieved via the Kyoto Protocol to the UNFCCC, which was adopted in 1997 and came into force in 2005. Under the Protocol, UNFCCC parties included in its Annex I (i.e., economically advanced, industrialized countries) made specific commitments to reduce GHG emissions during the first 'commitment period' from 2008 to 2012 relative to the base year (most commonly, 1990).

To facilitate achievement of this objective, the Kyoto Protocol provided that, first, Annex I parties could trade in unused parts of the allowed emission volumes among themselves; and, second, that an Annex I party could earn emission reduction units that counted towards its reduction targets by carrying out projects in the territory of another Annex I party or in the territory of a non-Annex I party.

A narrow set of industrialized countries with specific reduction commitments, especially in the second commitment period of 2013–2020, prevented the Kyoto Protocol from changing the rising trend in global GHG emissions. On the positive side, however, according to some analysis, the Protocol succeeded in facilitating a reduction of GHG emissions of its parties by approximately 7% below the emissions expected under a "No-Kyoto" scenario.[40]

The Kyoto Protocol's limited results in bringing about substantial emission reductions had parties to the UNFCCC rethink the overall approach. The 2015 Paris Agreement adopted at the 21st meeting of the Conference of the Parties to the UNFCCC thus set a numerical objective of 'holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C…' (Article 2.1(a), emphasis added). This is to be achieved through 'nationally determined contributions' (NDCs), i.e., voluntary emission reduction targets. These are however, technically, not legally binding commitments. Importantly, each party to the Paris Agreement decides for itself the magnitude of the contribution it intends to make and the means to make it happen. In other words, the Paris Agreement does not provide for either uniform emission reduction targets or a uniform pace of their achievement.

Box 1.1: How the 2°C and 1.5°C Targets Came About

In 1988, the World Meteorological Organization and the UNEP set up the IPCC to provide governments with scientific information they needed to devise climate measures. The IPCC, whose creation was endorsed by the UN General Assembly and which is made up of representatives of its 195 members, issues 'Assessment Reports'— comprehensive reviews of 'the state of scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place' (ipcc.ch).

In 2010, the 15th meeting of the UNFCCC Conference of the Parties 'took note'[41] of the 'Copenhagen Accord' of 18 December 2009 which stated, relying on the 2007 IPCC Fourth Assessment Report, that global emissions had to be cut 'so as to hold the increase in global temperature below 2°C'[41] and called for 'consideration of strengthening the long-term goal … in relation to temperature rises of 1.5 degrees Celsius'.[41] Scientific evidence suggests that larger temperature increases may result in crossing 'tipping points'[42,9] beyond which dangerous climate change will accelerate and its adverse effects will become irreversible.

1.2 Carbon Budget and Paris Agreement-Consistent Emission Pathways

The global surface temperature appears to rise proportionally to the total amount of CO_2 emitted over years ('cumulative CO_2 emissions'), so that each additional 10^{12} tons of CO_2 (1000 $GtCO_2$) emitted brings the temperature up by around 0.45°C [38] (Figure 1). This means that achieving the Paris Agreement targets, i.e., keeping the temperature increase below 2°C or 1.5°C, requires putting a cap on the cumulative amount of CO_2 that can still end up in the atmosphere. In other words, there is only so much CO_2 that can additionally be emitted before the thresholds are inevitably—and potentially irreversibly—transgressed. This amount is referred to as the 'remaining carbon budget.' The total amount of CO_2 that can be emitted without breaching the Paris thresholds counting from the pre-industrial period is referred to as the 'total carbon budget.'

The carbon budget already spent up to 2019 is estimated to likely fall within the 2390±240 $GtCO_2$ range. The low-end assessments of the remaining budget, reflecting an 83% probability to keep within the 1.5°C and 2°C limits, are 300 GtCO2 for the 1.5°C limit and 900 $GtCO_2$ for the 2°C limit. The high-end assessments for the same thresholds, which correspond to a 17% likelihood, are 900 $GtCO_2$ and 2300 $GtCO_2$, respectively.[38]

With the current annual global emissions at 42±3 $GtCO_2$, [9] the remaining budget is set to be exhausted rapidly—for the low-end assessments, within as little as a few years to a couple of decades. Staying on budget for a longer period therefore requires peaking anthropogenic CO_2 emissions in the next few years and gradually decreasing them to a net zero level, where any residual anthropogenic emissions must be offset by anthropogenic carbon removals, by around mid-century (and then further reducing them to net negative levels).

Every ton of CO_2 emissions adds to global warming

Global surface temperature increase since 1850-1900 (°C) as a function of cumulative CO_2 emissions (gigaton CO_2)

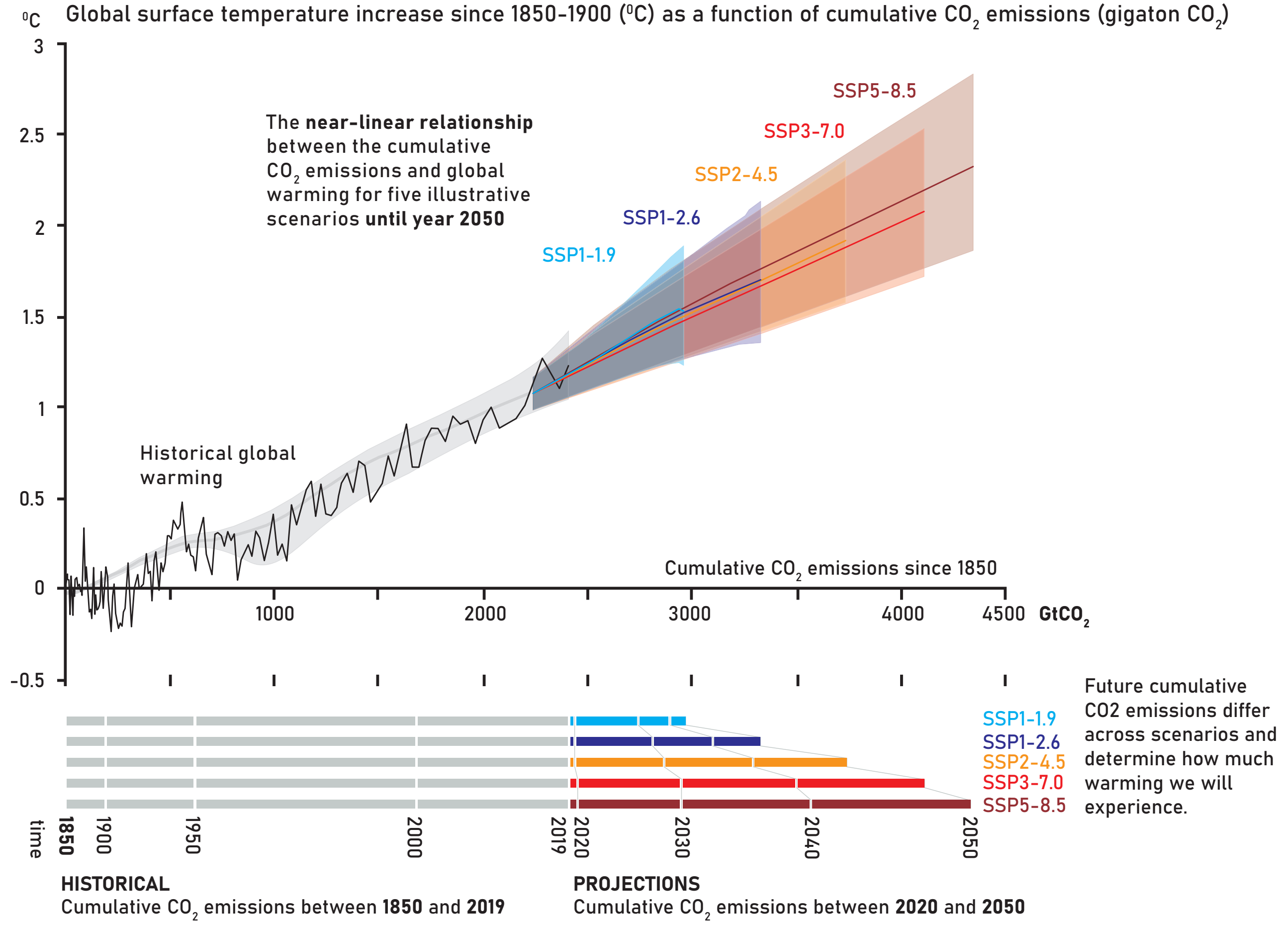


Figure 1. A near-linear relationship between cumulative CO2 emissions and the increase in global surface temperature.
Source: IPCC (2021).

Figure 2 illustrates this by showing all the different 'pathways' (emission scenarios) with no or limited overshoot of the 1.5°C target, meaning no crossing of the 1.5°C threshold or a temporary crossing of the 1.5°C threshold by no more than 0.1°C (the light blue area), and with a higher overshoot (the grey area). A higher overshoot in the short to mid-term obviously entails steeper and deeper emission cuts in the mid- to long term. The right-hand panels on Figure 2 show the corresponding pathways for other GHG emissions (the dark shaded area denotes the 5—95% range, the light shaded area denotes the 25—75% range).

1.3 Carbon Sequestration for Reaching the Paris Agreement Targets

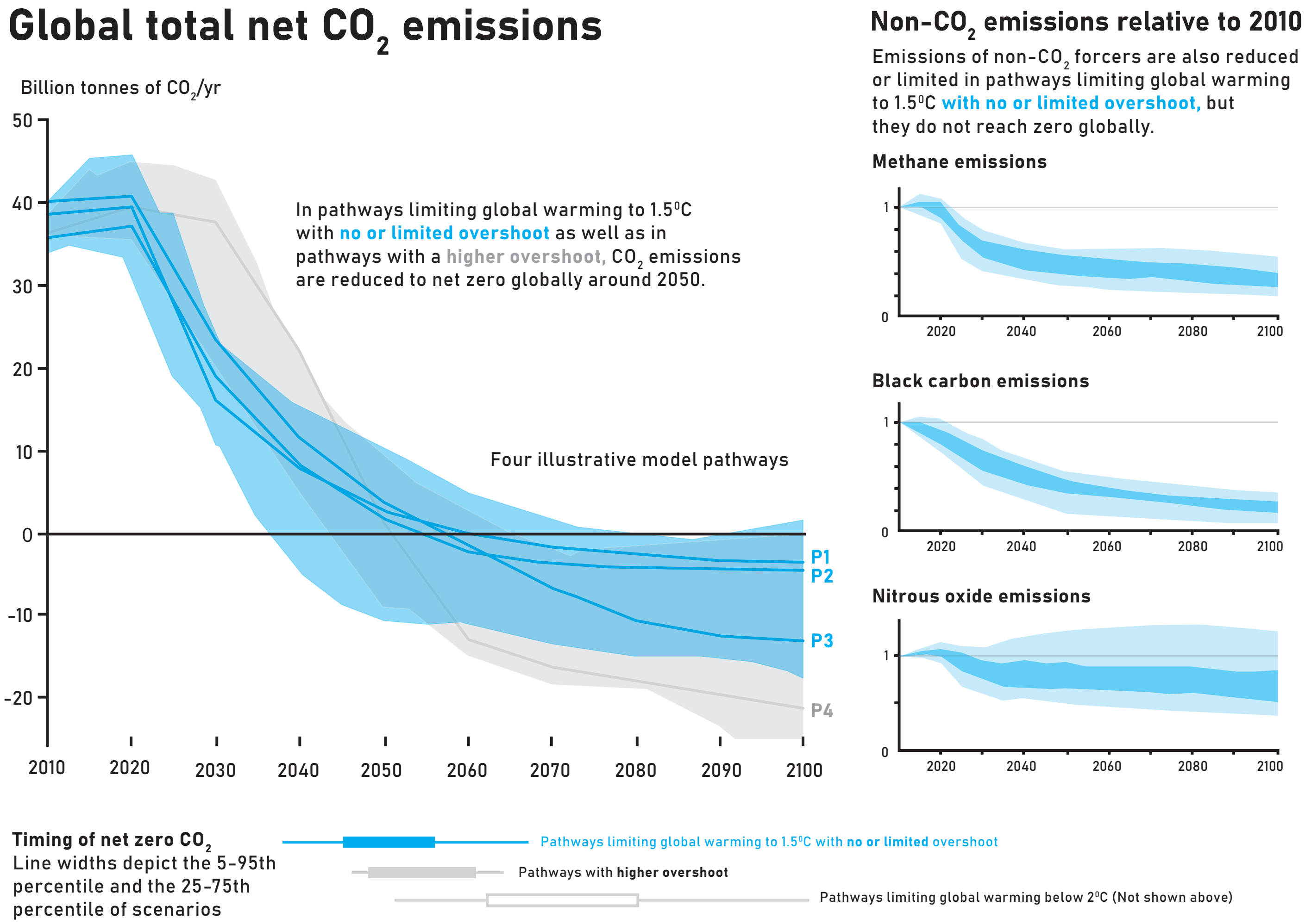


Figure 2. Global Emission Pathways. Source: IPCC (2018).

Time to reach net-zero emissions has become a metric for climate change mitigation ambition[43] with 136 countries having adopted or proposed their net-zero targets as of 1 September 2022.[44] These targets cannot be realized without taking CDR measures, also known as Negative Emissions Technologies (NETs) or carbon sequestration methods. To reach net-zero anthropogenic emissions, CDR technologies will need to be deployed to compensate for residual GHG emissions that cannot be fully eliminated (e.g. in transportation).[45] Furthermore, the deployment of CDRs is necessary to drive the net anthropogenic CO_2 emissions to levels below zero to compensate for temporary carbon budget overshoots[45] or to enable faster cooling-down of the global surface temperature as the accumulated oxygen dioxide will persist in the atmosphere for decades or even centuries, the temperature will not start falling immediately after net zero anthropogenic CO_2 emissions are reached and the effect of other GHGs on global surface temperature is not positive.[43] Before the end of the century, 100 to 1000 $GtCO_2$ will have to be captured from the atmosphere through CDR and stored in carbon sinks, i.e., natural or artificial reservoirs.[9]

The role of CDR is somewhat less pronounced in 2°C-consistent pathways for the simple reason that such pathways offer more leeway in the timing and stringency of emission reductions. Many models, however, envisage significant application of CDRs, in the range of 5 to 21 $GtCO_2$ per year, at the end of the century even in 2°C scenarios,[45] and further delays in putting pledges into practice will only be driving these numbers up. The scale of CDR required will largely depend on the extent to which gross anthropogenic emissions are reduced in the first place. The steeper and quicker are emission cuts, the less accumulated CO_2 there is to sequester using CDR.[45]

However, it would be erroneous to view CDR as a license for relaxing emission reductions. Rather, CDR should be seen as an auxiliary tool that can complement emission reductions—but not replace them.[43] As will be seen from the description of the various CDR practices that follows, their potential is not unlimited and often comes with a variety of trade-offs. If deployed wisely, however, CDRs can bring economic and social as well as climate benefits. The 26th UNFCCC Conference of the Parties (COP26) has explicitly endorsed trading in carbon credits generated from emission removal and reduction projects under Article 6 of the Paris Agreement and their use towards meeting countries' NDCs.[46]

1.4 The Potential, Costs, and Benefits of Various Carbon Sequestration Methods

Two major classes of carbon sequestration technologies exist. Geological sequestration uses industrial processes to capture carbon from the atmosphere (DACCS) or from biomass (BECCS) and store it in geological formations. Biological sequestration refers to the sequestration of carbon by ecosystems and its storage in terrestrial (plants, soils, wetlands) or ocean reservoirs, or, alternatively, in carbon-storing materials, such as plant-based materials and products, e.g., construction materials using straw.

DACCS is an umbrella term for technologies that use different sorbents to withdraw CO_2 from the surrounding atmosphere. The main technological limitation of DACCS is that its net CO_2 removal performance ultimately depends on the availability of low-carbon energy for the capture process.[47] Thus the net effect of a natural gas-fuelled DACCS plant may be just 'a fraction of'[45] its installed capture capacity while a coal-fueled plant may, on balance, end up producing positive, rather than negative, emissions.[45,48] The second limitation is economic as DACCS is the most expensive carbon sequestration technology out there. As it is not yet operating at scale, only estimates of DACCS costs are now available. It is expected that as more plants are built, the cost would decline from US$ 350—700/tCO2 stored (depending on the source of energy used) to below US$ 200/tCO_2 stored. [49] The costs are driven up by high capital and operating expenditures and are mitigated to some extent if the plant is located close to the storage facility and renewable energy sources it relies upon.[45,50]

The upside of DACCS is that storage in geological formations offers excellent permanence (see chapter 4.2) in the order of centuries to millennia with leaks not thought to be a major issue.[45] There is, however, vast uncertainty about (1) the geological storage capacity available globally with estimates ranging from 320 to 50,000 $GtCO_2$ [45,51,52] and (2) the geo-mechanical response[43,53] and the ecological effect[45] of large-scale CO_2 injection into geological reservoirs.

Due to its high cost and technological uncertainties, DACCS is relegated to a secondary role in the 1.5°C- and 2°C-consistent pathways modelled to date and some mitigation pathways omit DACCS entirely.[47] It is BECCS that takes center stage instead. The median estimate for cumulative CO_2 removal using BECCS from 2020 to 2100 stands at 328 Gt; the median estimate for annual CO_2 removal using BECCS in 2050 is 2.75 Gt per year. This is to be compared with 29 Gt and 0.02 Gt per year for DACCS, respectively[47]

BECCS is essentially a two-component (BE + CCS) approach. First, mitigation is achieved by using biomass, instead of fossils, to produce energy as carbon emissions that are generated in the production process are fully or partially offset by carbon sequestration during biomass growth. Second, the process becomes a CDR technology if emissions from energy production are captured and stored (e.g., in geological formations). BECCS is the dominant approach now (followed by land sequestration discussed below) accounting for the lion's share of CDR across modelled pathways that keep temperature rise below the 1.5°C and 2°C thresholds.[47] It combines the benefits of geological storage (high permanence and storage volumes) with those of biological sequestration, such as reasonable costs, starting from US$ 15/tCO_2. The lower cost estimates normally assume unimpeded access to enough biomass and proximity to storage facilities. Cost estimates are also strongly dependent on the technology used.[45]

One major area of concern in relation to BECCS, however, is availability of land to grow enough biomass to be used as feedstock for bioenergy. 'The availability of biomass and land,' it has been noted, 'is seen as the fundamental limiting factor, structuring discussions about BECCS potentials.'[45,54,55,56] There are a few reasons for such a concern. First, bioenergy crops compete for land with food/feed crops, which may put pressure on global food supply and adversely affect food security. This concern is partially addressed by advanced (second-generation) biofuels which are produced from non-food biomass, including agricultural residues and waste (by-products of food/feed production), which either does not require additional land or can be grown on marginal lands, not suitable for food production. This has not taken competition for land completely off the table, though.

Second, cultivation of bioenergy crops often results in conversion of land, e.g., from forest to agricultural land, which often leads to increase in GHG emissions. Such land use change may be direct, e.g., resulting from clearing of forest for bioenergy crop cultivation (LUC), or indirect, resulting from clearing of forest for cultivation of food or feed crops that would otherwise could have been grown on land used for growing bioenergy crops (ILUC). LUC/ILUC is estimated to impose a 10 to 30% 'efficiency penalty' on BECCS as a CDR technology.[45]

Finally, industrial cultivation of bioenergy crops is associated with the same side effects as any industrial agriculture. In particular, the high levels of BECCS carbon abatement potential used in integrated assessment models rely on expected improvements in bioenergy crop yields which may go hand-in-hand with more extensive application of fertilizers and thus higher GHG emissions, in particular N_2O.[45]

Afforestation and reforestation (AR) is the most common among biological CDR methods. Afforestation refers to the planting of forest on what historically (normally for 50 years or longer) has been a non-forest land, while reforestation is the planting of forest on a recently deforested land.[45] There is also forest restoration which is 'a form of reforestation that gives more priority to ecological integrity as well….'[57] Carbon sequestered through photosynthesis is then stored directly in plant biomass (leaves, wood, roots)—or in soils. Without cost considerations, AR projects may add from 0.5 to 10 GtCO_2 per year to carbon sequestration volumes in 2050.[57]

Two major upsides of sequestration through AR are low cost and positive side effects, in particular environmental co-benefits (not least, biodiversity and surface water runoff and groundwater recharge). Implementation costs for AR projects are estimated to start as low as US$ 1 /tCO_2 sequestered with developing countries having a clear cost advantage vis-à-vis more industrialized states.[45] According to some estimates, up to 3 GtCO_2 per year, or 30% of the technical potential referred to in the previous paragraph, can be removed in 2050 at cost below US$ 100/tCO_2.[57]

Forests being a major sink, i.e., an absorber and accumulator, of carbon, AR as well as the revival of recently drained/dried wetlands (e.g., for peat production) act on the root of the problem by restoring or creating sinks that seamlessly fit into the natural carbon cycle. The IPCC Sixth Assessment Report states in this respect: ‘Well-planned, sustainable reforestation and forest restoration can enhance climate resilience and biodiversity, and provide a variety of ecosystem services including water regulation, microclimatic regulation, soil erosion protection, as well as renewable resources, income and livelihoods.’[57] ‘Afforestation, when well planned, can help address land degradation and desertification by reducing runoff and erosion and lead to cloud formation.’[57]

However, industrialization of AR, i.e., the planting of large swaths of monoculture trees, especially of non-native and/or invasive species, with the sole purpose of creating a carbon sequestration machine without due regard for how this will affect the larger ecosystem is prone to creating adverse effects, e.g., on water availability and biodiversity, that may detract from the benefits of this NET. The albedo effect discussed above may act in opposite directions depending on the latitude—while creating a cooling effect by increasing reflection of solar radiation in tropics and subtropics, it becomes counterproductive moving further away from the equator and towards the poles. Some studies even suggest that due to the impact on albedo, there is no use for AR outside of tropical regions.[45, 57] In those regions, however, competition for land with food/feed/bioenergy crops may be especially tight.[45, 57]

An important downside of more sustainable AR projects is considerably lower permanence of carbon storage as compared to geological storage. Avoiding release of carbon locked in felled wood and green biomass requires an industry that puts them to use which prevents reversal, i.e., as construction materials. Moreover, with forests, there is always a risk that sequestered carbon will be released back into the atmosphere as a result of forest fires, pest outbreaks, or illegal felling, though these risks can be mitigated, at least partially, by improved forest management. Forest sinks also have a relatively short saturation period (normally, a few decades) as there is only as much carbon as a tree may absorb throughout its lifecycle.

Soil carbon sequestration (SCS) in croplands and grasslands is considered to be the second most important biological CDR technology in terms of its sequestration potential (0.4 to 8.6 GtCO2e per year globally) losing only to AR (0.5 to 10.1 $GtCO_2e$ per year globally).[57] SCS is achieved by adopting land management practices which either increase carbon input into or reduce carbon loss from soils.

Soils are the largest terrestrial carbon reservoir whose capacity is estimated to be 1.8 times that of the atmosphere and 2.3-3.3 times that of terrestrial vegetation.[58] In an environment with elevated CO_2 levels, SOC stocks have also been found to be negatively related to plant biomass, which means that carbon sequestration by plants may be at the expense of SOC content in soils.[13] A recent meta-analysis of experimental data showed that a 21% to 25% increase in forest plant biomass results in forest SOC stock either increasing or decreasing by up to 2%, while an increase in grassland plant biomass by 6% to 12% is associated with an increase in grassland SOC stocks by 6 to 10%.[13] This means that non-forest terrestrial ecosystems which accumulate carbon in soils may be as (or even more) important for climate change mitigation than forests.

This insight inspired the ‘4 per 1000’ initiative whose title reflects the underlying idea that an annual increase in the global soil carbon content in the upper layer of soil by 0.4% (i.e., 4‰) would be tantamount to removing a year-worth of global anthropogenic emissions of CO_2 from the atmosphere.[59] Inaugurated at the 21st Conference of the Parties to the UNFCCC in 2015, the initiative aims to ensure that by 2050 ‘[a]ll UNFCCC Parties include quantitative targets for [soil health] and SOC in their NDCs and related documents and reference them in their national plans and programs for agriculture, forestry, and land use.’[60] As of 2019, only 28 out of 196 NDCs met this target.[60]

Although the cost of implementing SCS measures is highly dependent on the particular conditions of the land in question and the current practices applied to it, SCS is considered 'a low-cost option at a high level of technology readiness… with low socio-cultural and institutional barriers.'[57] Some practices, such as, for instance, no-till or reduced tillage intensity, may in fact be economically viable even without external financing.

As is the case with AR, SCS's limitations are related to the risks of (i) wind and water erosion of soil and (ii) non-permanence and shorter saturation time—the annual sequestration potential of each parcel of land decreases as its SOC stocks increase. To prevent sink reversal and carbon leakage, SLM practices have to be maintained even after saturation.[45]

Other biological CDR methods discussed in the literature include, for instance, **enhanced weathering (EW)**,[45] i.e. acceleration of the natural decomposition of mineral-containing rocks (e.g., basalt) by comminuting them to increase air contact surface and spreading them on land or in the ocean to absorb atmospheric CO_2.[14] Or **ocean fertilization**, i.e., adding nutrients (e.g., iron) in the upper layers of the ocean to stimulate growth of phytoplankton (algae), which absorbs carbon through photosynthesis.[14] The potential of these CDR technologies when deployed at scale (as opposed to laboratory conditions) requires further research. In this regard, the IPCC Sixth Assessment Report assigns to EW a score of 3-4 for technology readiness level on a 1 to 9 scale, where 1 stands for 'basic principles defined' and 9 for 'proven in operational environment.' Ocean fertilization is rated even lower at 1-2 while BECCS was given a 5-6 and DACCS a 6. All of these CDR technologies, except for BECCS which features prominently in current models, also play a secondary role in the 1.5°C- and 2°C-consistent pathways.[14]

At the same time, soil carbon sequestration alongside AR are estimated to have the highest levels of maturity with a 8-9 score.[14] Combined with the lowest implementation costs,[57] these CDRs stand out as feasible and effective means for climate change mitigation. The Supervisory Body designated to supervise the trading mechanism under Article 6.4 of the Paris Agreement has recently concluded that 'land-based [removal] activities are proven and safe, have a long history of practice … have the potential to the deliver cost-effective CO_2 mitigation required by 2030'.[15] In addition to carbon sequestration, land-based removal activities can 'generate significant sustainable development co-benefits',[15] which will be discussed in more detail in the Chapter.[6]

2. Land-Based Carbon Sequestration in Kazakhstan's Drylands

2.1 The Challenge of Land Degradation in Drylands

Land is defined as 'the terrestrial portion of the biosphere that comprises the natural resources (soil, near surface air, vegetation and other biota, and water), the ecological processes, topography, and human settlements and infrastructure that operate within that system.[58] Land-based carbon sequestration will achieve the highest impact on lands that have lost a considerable share of their SOC stock and whose carbon storage capacity is therefore largely unfilled. Degraded drylands are a prominent example of such landscapes.

According to the UNCCD, land degradation refers to the reduction or loss of the biological or economic productivity and complexity of land resulting from land uses or from a combination of processes including human activities and habitation patterns (UNCCD 2023). Three specific land degradation processes typical to drylands are included: soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation. Soil degradation, on the other hand, is 'a subset of land degradation processes that directly affect soil.'[58]

Kazakhstan estimates about 21%, or 57Mha, of its total land area to have been degraded,[4] including 27 Mha of rangelands.[5]

Box 2.1 Land Degradation Neutrality (LDN) Targets.

In 2015, UNCCD Parties were invited to formulate voluntary targets to achieve LDN in accordance with their specific national circumstances and development priorities. To date, 131 countries have committed to setting LDN targets, and more than 100 countries have already set their targets including Kazakhstan and several other countries of Greater Central Asia. According to a 2018 Report,[62] Kazakhstan strives to achieve land degradation neutrality by 2030. Among the specific measures the country intended to undertake were measures to include fallow and abandoned lands in the turnover; measures to create woody and shrub plantations to protect the land from water and wind erosion, create a microclimate, improve soil fertility, snow and moisture retention; increase of the water fund to maintain water bodies in proper condition and the woodedness of the adjacent territories of the lands; measures to restore collector-drainage systems and to restore the land of liman irrigation; measures to improve rational use of agricultural land.

Human-induced soil erosion—i.e., 'detachment and transport of soil particles'[63] — by wind and water has been and remains the primary pathway of land degradation.[58,63] Soil erosion directly leads to the loss of SOC, which is mostly found in the low-density upper layer (0 to 20 cm) of soil and is easily removed by wind or water streams.[63] This and other physical degradation processes (e.g., soil compaction and hardening) may be enabled and exacerbated by other stress factors, such as, for instance, tillage or overgrazing.[58] Soil erosion of agricultural fields is estimated to progress at a rate 16 (no-till) to 380 (conventional tilling) that of soil formation (0.8 t/ha per year and 15 t/ha per year compared to 0.05 t/ha per year, respectively).[58]

Disturbance of the soil chemical balance is another driver of chemical soil degradation. It may result from a number of causes, including insufficient as well as excessive fertilization or heavy metal pollution.[58] Land in drier climates is also particularly vulnerable to degradation through soil salinization above natural ('primary salinity') levels, caused by a rise in the water table on lands that are over-irrigated or cleared from vegetation (the latter being associated with a decrease in water uptake). Salinization may also ensue from the desiccation of inland water bodies and the transportation of salty sediments to cultivated and natural lands.[58]

Conversion of natural ecosystems, such as grasslands, steppes and shrublands, into croplands or pastures or introduction of invasive non-native plant species may result in biotic land degradation, which might be also associated with SOC loss. By altering the microbial composition of soils, chemical pollution by residues of plant protection products or fertilizers may intensify soil respiration thus also increasing SOC release.[58]

Soil erosion is especially acute in dryland areas of the world,[63] including what has recently come to be known as the Asian Drylands Belt—the Greater Central Asia region with a total area of 15.4M km^2, which comprises lands in Central Asia (Afghanistan, Kazakhstan, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, Uzbekistan), East Asia (Mongolia and six China provinces — Gansu, Inner Mongolia, Ningxia, Qinghai, Tibet, Xinjiang), and the Middle East (Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Syria, Turkey).[64] Kazakhstan accounts for the largest share (18% or 2.7 million km^2) of the ADB area and Pakistan for the largest share of its population (31% or 197 million).[64] Kazakhstan and Mongolia are also the world's largest landlocked countries.[64]

Drylands are areas with a low water-supply-to-water-demand ratio, also known as the aridity index (AI). Water supply is expressed by the annual amount of precipitation, water demand—by potential evapotranspiration, i.e., the amount of evaporation from soils and transpiration from plant tissues with unrestricted water supply (Figure 3). Drylands are further divided into four subtypes with the AI ranging from below 0.05 for the hyper-arid type to below 0.65 for the dry subhumid type (Table 1). Accordingly, the UNCCD defines arid, semi-arid, and dry sub-humid areas as "desertification-affected or -threatened areas, other than polar and sub-polar regions, in which the ratio of annual precipitation to potential evapotranspiration falls within the range from 0.05 to 0.65.'[65]

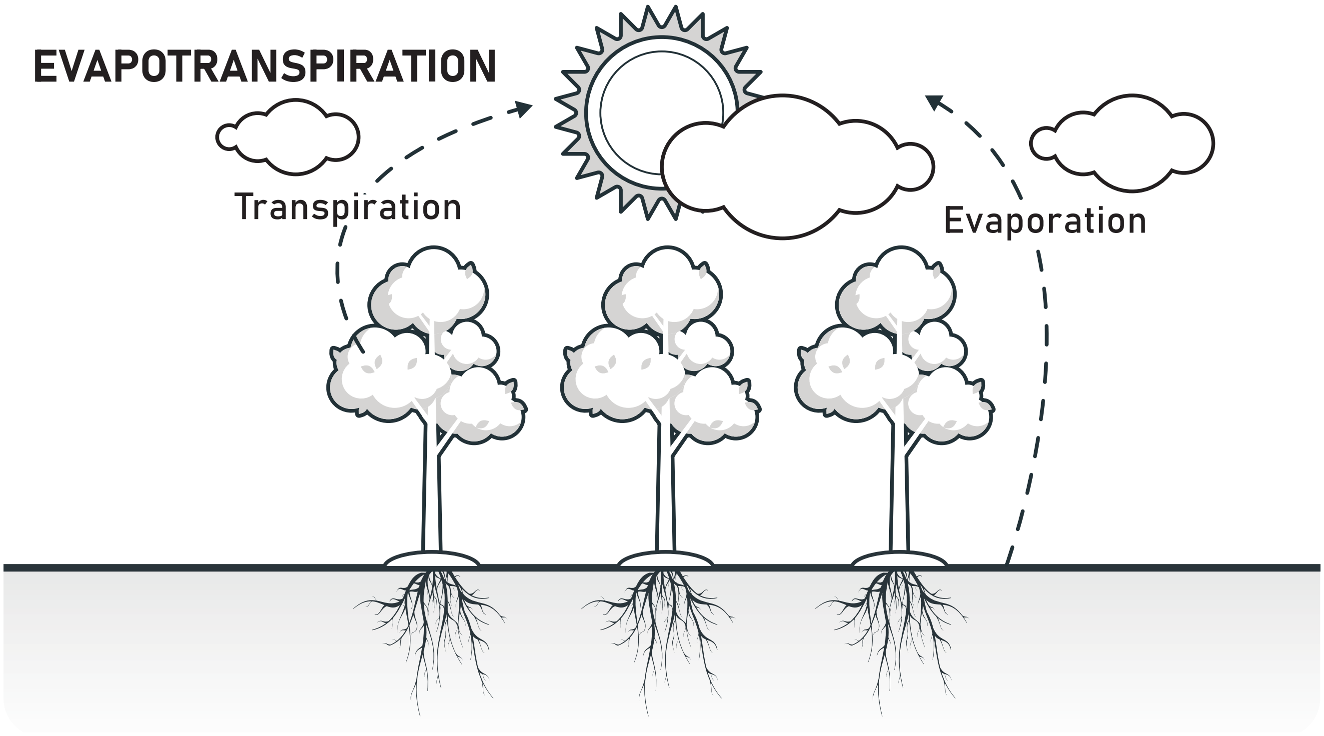


Figure 3. Evapotranspiration (schematically). Source: An author's elaboration

Climate Type	Aridity Index
Dryland subtypes	
Hyper-arid	AI < 0.05
Arid	0.05 ≤ AI < 0.2
Semi-arid	0.2 ≤ AI < 0.5
Dry subhumid	0.5 ≤ AI < 0.65
Non-drylands	
Humid	AI ≥ 0.65
Cold	PET < 400 mm

Table 1. Climate classification and dryland subtypes based on the aridity index.
Source: European Commission (2018).

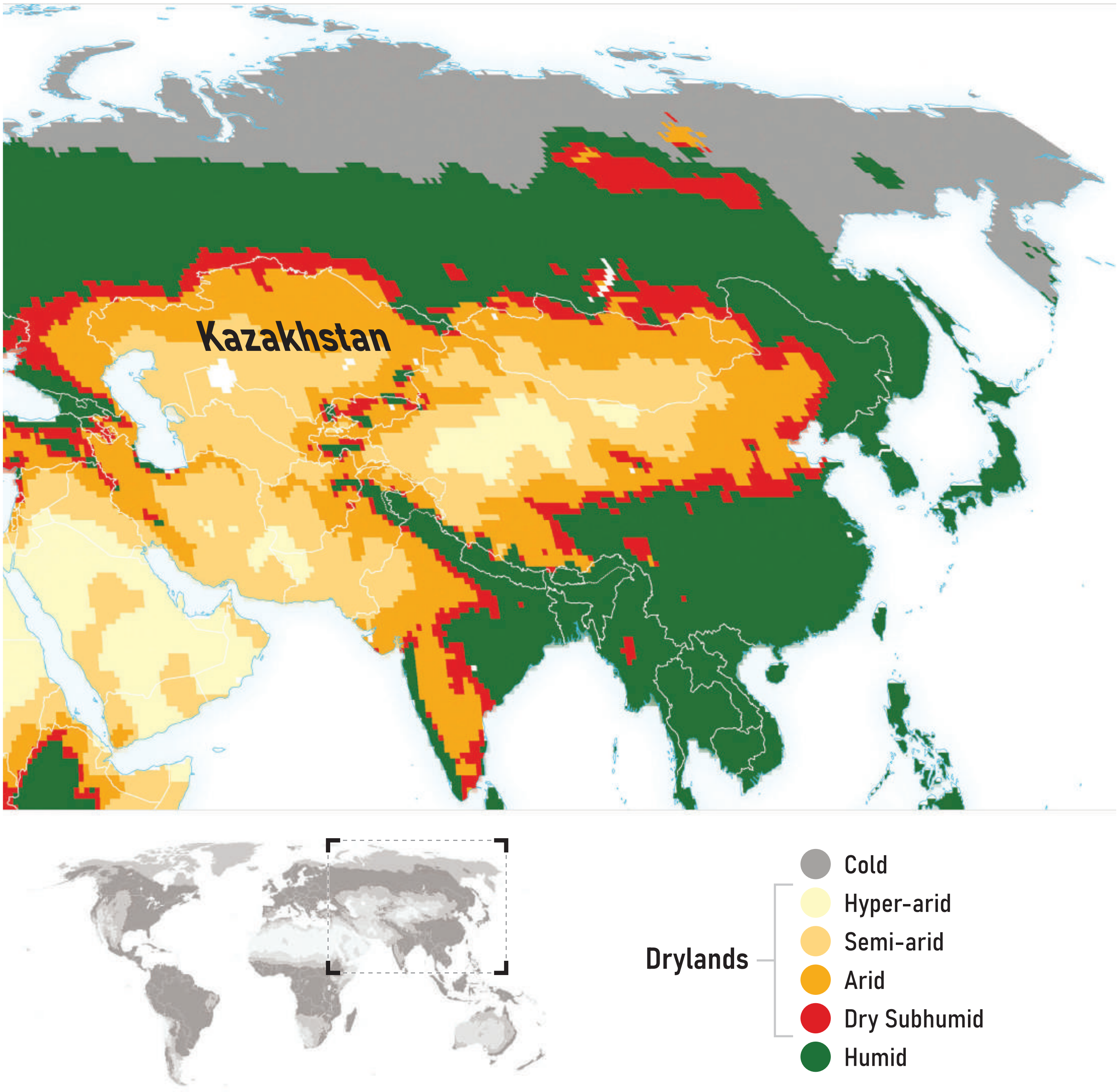


Figure 4. Climate types in Asian Drylands Belt in 1981—2010 by Aridity Index.
Source: European Commission (2018).

Kazakhstan is dominated by arid and semi-arid areas with just a tiny fraction of the country's territory located in the dry subhumid and humid climates (Figure 4). As a consequence, Kazakhstan's prevailing landscapes are deserts and semi-deserts with steppes and forest-steppe occupying a smaller area in the north (Figure 5).

Water scarcity, a defining feature of drylands, reflects in diminished gross primary production (GPP)—the amount of carbon captured by plants per unit of time through photosynthesis. Although it varies over the ADB within a wide range from 57 gC/m^2 per year in Afghanistan to 589 gC/m^2 per year in Türkiye,[64] it is way below, for instance, the forest GPP in the equatorial zone, which is estimated to fall between 1800 and 3000 gC/m^2 per year.[68]

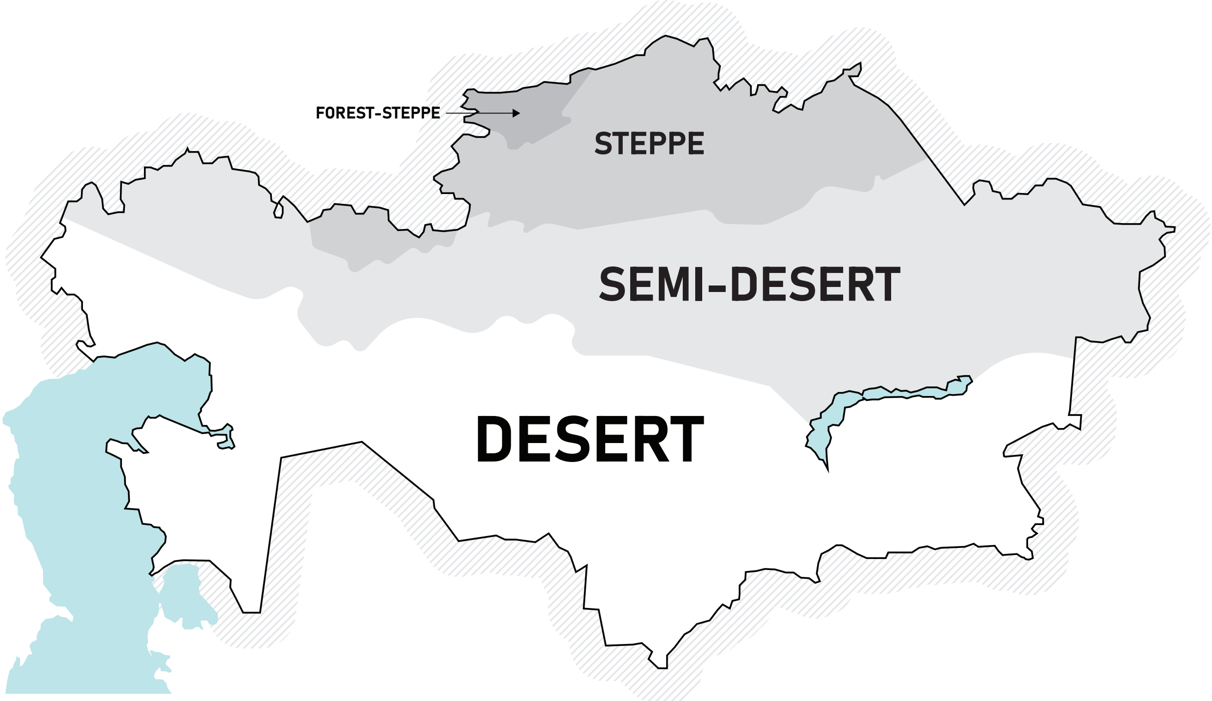


Figure 5. Kazakhstan's landscapes (schematically).
Source: An author's elaboration.

Rich in grasslands, which account for around 40% of its area,[64] the ADB had traditionally been known for nomadic pastoralism with livestock moved from one spot to another along with changing seasons and forage availability. Another 40% is represented by barrens (desert areas). Croplands and savannahs & shrublands account for ca. 10% and 7%, respectively.[64] The practice remained sustainable so long as animal stocking rates did not exceed the rangelands' carrying capacity. Rapid expansion of animal and crop farming in response to rising demand for animal and plant food products, driven by economic development and population growth over the past several decades, proved exhausting to the ADB's water-scarce ecosystems.[70] Vegetation degradation and wind erosion became two primary scourges for the stressed pastures.[71]

Three strategies have been employed to meet increasing demand for meat and dairy products, both involving a rising pressure on the environmental resources. One is to graze more animals on the same area, including beyond what the pastureland can sustain. While over 60% of rangelands were reported to have been affected by overgrazing globally, estimations for the ADB states vary widely—from 13% to 38% in Kazakhstan or from 15% to 90% in Tajikistan.[70,72,73,74] Kazakhstan's Eighth National Communication to the UNFCCC states that 20% to 60% of the country's pastures, depending on the region, are degraded.[5] The total area of degraded pastures is stated to be 27 Mha.[5]

The second strategy provides for more intensive industrialization of livestock production, i.e., relocation of animals from free-range fields to compact isolated spaces with concomitant change of diet from forage grasses to grain. Animal welfare issues aside, this strategy involves, in particular, conversion of grasslands, including marginal (low-productivity and/or overgrazed) lands, to croplands to grow feedstock. Irrigation systems—an indispensable element of crop cultivation in most of the ADB—place burden on the already scarce water resources and set in motion additional mechanisms of land degradation, such as soil salinization.[70] The processes at work are graphically illustrated by two examples: desiccation of the Aral Sea and degradation of the Lake Balkhash basin. A third strategy with similar effects is to convert grazing or unused lands into croplands (e.g., cotton, rice and vegetables in the Aral Sea basin or tobacco, fruits and vegetables in the Ili-Balkhash-Alakol basin) with produce exported and meat and dairy products imported to make up for shortages in supply.

2.2 Desiccation of the Aral Sea and Degradation of the Lake Balkhash Basin

A unique feature of the ADB is a large number of endorheic drainage basins which include freshwater lakes—the Lake Balkhash in Kazakhstan, the Lake Issyk-Kul in Kyrgyzstan, the Urmia Lake in Iran, the Sargamysh Lake in Uzbekistan and Turkmenistan, and the Qinghai Lake in western China[64] i.e., water systems that lack access to the ocean and are especially vulnerable to balance-disturbing influence.[75] There is a vicious circle of a kind that is at play: scarcity of water supply on drylands mandates coping strategies that include diversion and/or impoundment of water streams, which, as the cases of the Aral Sea and Lake Balkhash so tellingly demonstrate, exacerbates the problem in the long run, puts pressure on the surrounding ecosystem, and produces negative social side-effects.[76]

While fluvial water has been used for irrigation of farming lands from the early days of human history, it is the rapid expansion of crop fields in the second half of the twentieth century that put Asian drylands to a stress test.[76] After the irrigated agricultural land, not least that located foremost on the border between Kazakhstan and Uzbekistan, grew from 5 million to 7.9 million hectares (consisting mainly of water-thirsty cotton and rice plantations) between 1965 and the 1990s, the decline in water discharges into the Aral sea from both the Amu Darya and the Syr Darya rivers became so significant that it could not be compensated for by slower evapotranspiration in particular, as a result of decreasing water surface.[76] As a result, already by 1989, the sea had split in two (and later, three) water bodies connected by a channel which dries out during some periods of the year. The total surface area of the two seas had shrunk by 74% and their total volume by 90%.[76]

What once was the world's fourth largest inland lake (referred to as a 'sea' for its sheer size) turned into 'the largest inland salt reservoir.'[77] Salinity rose from 10 to 70–80 g/l in the smaller and to over 100 g/l in the larger of the two seas—levels that preclude survival of native fish species.[76] Winds carry dust and salts from the seabed laid bare and irrigated soils up to 500 km away, inflicting major harm on the health of plants, animals, and humans in the neighboring areas of Kazakhstan, Uzbekistan, and Turkmenistan. Inhibited growth of wild and cultivated plants translates in lower crop yields; animal diseases similarly lead to reduced food supply while agrochemicals mixed with dust exacerbate adverse public health effects.[76] In addition to the adverse impacts on local biotic communities, the drying-out of most of the Aral Sea has had profound effects on the local climate: 'Maritime conditions have been replaced by more continental and desertic regimes. Summers have warmed and winters cooled, spring frosts are later and fall frosts earlier, humidity is lower, and the growing season shorter. … the increase in the levels of salt and dust in the atmosphere are [also believed to be] reducing surface radiation and thereby photosynthetic activity, as well as increasing the acidity of precipitation.'[76,78]

Since the turn of the 21st century, following the Government of Kazakhstan's extraordinary efforts to address the Aral Sea problem—in particular, by separating with a dam the northern part of the sea from the rest of what once was a single water body —the 'Northern Aral Sea' (or the 'Small Sea') has been recovering as a result of larger water discharges from the Syr Darya. The other parts of the sea, however, remain in a disastrous condition due to acute shortage (or complete absence) of water supply from the Amu Darya—in dry years, massive water uptake for irrigation during the vegetation period in Uzbekistan as well as other upstream countries (Afghanistan, Tajikistan, and Turkmenistan) prevents the river from reaching the Aral Sea.

The Ili River/Lake Balkhash in Kazakhstan and China (Figure 6) is another endorheic basin ecosystem whose condition the Kazakhstan's Eighth National Communication to the UNFCCC describes as 'critical.'[5] In China's upstream segment of the river, the ecosystem's water balance had been disturbed by a rapid expansion of irrigated crop fields in the late twentieth and early twenty-first century, including into overgrazed pastures. Water from the basin is also used to feed hydro power plants, which have been built lately to meet energy demands of China's developing western provinces.[75]

Figure 6. The Ili River ecosystem.
Source: Pueppke et al. (2018).

In Kazakhstan, the nearly unpopulated Ili delta (the only part of the river basin suited for non-irrigated agriculture) has long been used as a grazing land which 'with current numbers of cattle, sheep, and goats, estimated to be 39,000, 23,000, and 29,000, respectively, greatly outnumber[s] the delta's human inhabitants.'[75] After the Kapchagai dam and reservoir were built in 1965–1969 to provide hydropower as well as irrigation for hundreds of thousands of hectares of crop fields of the local 65 kolkhozes (collective farms), the water got contaminated with pollutants from the irrigated fields, its level went down 2.3 m, the delta shrunk and its salinity increased.[75,79,80,81] The only reason why the terminal Lake Balkhash has not eventually dried out is supposedly due to the fact that the scale of irrigated areas never reached the original targets.[75] At the same time, expansion of croplands achieved came at the expense of animal husbandry and fishery: 'Two-thirds of the pastureland in the delta dried out by the early 1990s, forcing herders to drive their animals into the floodplain, where grazing inflicted further damage on an ecosystem already suffering from water shortages.'[75,82]

These two examples graphically illustrate the close interlinkages and tradeoffs between water availability, food supply, and energy generation – the so-called food-water-energy nexus – in dryland areas characterized by water scarcity. Without reservoirs, hydraulic structures only serve to redistribute—but are unable to increase—the total volume of available water, hence any gain for irrigated crop fields results in increased pressure on non-irrigated cultivated and grazing lands. It is exacerbated by diversion of water for energy production, when it is done without giving considerations to possible negative impacts:

> *When reservoirs are created, productive [lands] along rivers are often submerged, displacing food production to less suitable areas. Irrigated croplands often replace pastures [reference omitted], and such expansion increases the demand for highly energy-intensive nitrogen fertilizers, the use of which is increasing in Central Asia [reference omitted]. Irrigation and maintenance of pastures suitable for livestock require electricity to power pumps and other infrastructure that lift and move water [reference omitted], and so factors that limit the availability or raise the price of energy often lessen food production [reference omitted]. High energy prices have, in fact, contributed to a decline in aquaculture along the Ili River in Kazakhstan [reference omitted], and in neighboring Uzbekistan, where three-quarters of the entire annual budget for the Ministry of Agriculture and Water Resources is spent on pumping water [reference omitted]. With the exception of gravity-fed areas, all of the irrigation districts fed by the Kapchagai reservoir now lie fallow, because costs to raise water from the impoundment to the agricultural fields are prohibitive. This includes areas such as Shengeldy, which lie within sight of the reservoir.*[75,83,84,6,85,86,87]

These and similar dynamics lie at the center of human-induced land degradation in the region, reinforced by the natural vulnerability of arid and semi-arid ecosystems[75,88,89,90,91] — and even more so, of endorheic water basins — to climate variability.

2.3 The Impact of Mining Sector on Dryland Economies and Land Degradation

Along with nomadic pastoralism, mining for minerals has for millennia been a characteristic feature of the lifestyle in the ADB latitudes with fossil fuels added to the production portfolio more recently. A number of ADB economies have built their growth strategy of the last several decades on a rapid expansion of the extractive sector. For instance, coal accounts for 80% of Mongolia's exports[15] and 50% of energy generation in Kazakhstan.[10] In both countries proceeds from natural resource extraction enabled double-digit growth rates in the first decade of this century.[92,10] Kazakhstan exports 80% of oil it produces.[10] China's coal-fired power plants contribute the lion's share to the electricity and heat generation sector's 45% cut in the country's GHG emissions.[93] Additionally, China supplied up to 90% of the world's demand for rare earth metals in 2008—up from 27% in 1990.[246]

Two aspects of this strong reliance on the extractive sector are important in the context of GHG emissions and land-based carbon removals. The first one is competition between mining and agriculture (animal husbandry and crop farming) for land, water, and other limited resources, which has become yet another driver of land and environmental degradation in the region.[94] As mining consumes tremendous amounts of water, it also deprives herders even of what little is left after water diversion to irrigation and energy generation.

Secondly, strong reliance on the extractive sector predetermines the countries' high GHG emission levels—and a high carbon footprint of their exports. A World Bank report describes Kazakhstan's per-capita GHG footprint, which saw a two-fold increase from 2001 to 2018 and landed the country in 20th place worldwide, as 'outsized,' even if the GHG emissions of Kazakhstan's oil and gas fall in the middle range.[10] The reason is high carbon intensity of Kazakhstan's fossil fuel-based energy and heat generation, which represent 84% of the country's total emissions.[10] Similarly, China's high reliance on coal-fired power generation (57% of energy consumption and 60% of electricity generation)[93] explain an elevated emission intensity of its GDP.[93]

Emphasis on the mining sector in Kazakhstan in the early 21st century was associated with a decline in its Economic Complexity Index ranking[95] potentially reducing the resilience of the country to economic shocks. In this context, the adoption of SCS may support Kazakhstan's ongoing efforts towards diversification of its economy. Furthermore, SCS can increase diversification in crop farming reducing the share of water-intensive and monoculture crops.[5]

2.4 Climate Change Impact on Dryland Economies

Climate change manifests differently across the ADB. While some parameters, e.g., the mean annual precipitation, do not demonstrate a pronounced trend in most of the region as yet, the direction of change in others, e.g., an increase in the mean annual temperature, is evident. [64] The areas with a significant upward trend encompass, in particular, most of Kazakhstan whose southwestern part is especially prone to a rise in aridity and has also been highlighted as a hotspot of land cover change from 2001 to 2016 [64] when its forest lands shrank by 19% and its shrubland area expanded by 166%.[64]

As evidenced by the story of the Aral Sea, depletion of water basins often triggers a positive feedback loop leading to further deterioration of local climate conditions. By causing the melting of glaciers and the drying-out of rivers and lakes, hiking surface temperatures are poised to exacerbate water scarcity. This will add to the adverse effects on water from human activities, such as water diversion to irrigation due to expansion of crop fields and grazing lands, and, in some contexts, energy generation.[64] Extreme weather events, including droughts and intense precipitation, will become more prolonged and severe: 'The future climate of the ADB is … expected to be warmer, dryer, and more even in distribution [across the ADB] as compared to today.

Importantly, climatic variation, especially extreme events such as drought, extremely cold winters, and heatwaves from late spring through the summer, will escalate and threaten to tip ecosystem function and disrupt human wellbeing.'[64] By creating conditions which are even more conducive to land degradation,[96] climate change is likely to put pressure on crop yields and livestock productivity while also reducing the diversity of vegetation cover.[96] The severity of these effects will be a function of a number of variables, including population growth, evolution of consumption patterns, and technological advancement.[96]

In Kazakhstan, the rise in the mean surface temperature—which has already crossed the threshold of 1.5°C above pre-industrial levels between 1850 to 1990 [6] and, according to some models, may reach 3°C to 4°C or even 6°C[5] in the business-as-usual (BAU) scenario[5] — is expected to result in less precipitation in summer and more in winter (which will require more facilities to store winter water for summer needs). This increases the role of soil moisture stocks for yields during the vegetation period.[6] Soil moisture, however, has been declining in the northern and western regions, in which the climatic conditions are more suited for crop farming.[10] Expansion of irrigated arable lands by 67% (from 1.8 Mha to 3 Mha) to 2030 and rising temperatures are projected to increase both total and per-hectare water consumption for irrigation.[5] In southern regions which are heavily dependent on irrigation, water consumption is estimated to go up by 14%,[10] putting additional pressure on the local lands and ecosystems. Kazakhstan's Ministry of Ecology forecasts water deficit of 11.7 km^3 in 2030, or 88% of water withdrawal in 2020 (13.3 km^3).[5]

The yields of spring wheat, Kazakhstan's main crop (produced mostly on non-irrigated lands) which accounts for more than 50% of the country's sown area,[97] are highly sensitive to water availability[98] with 80% of yield variability determined by the water factor and only 8% and 12% by light and heat, respectively. [99] An increase in evapotranspiration due to the increasing surface temperature will exacerbate water deficit. By 2050, evapotranspiration from spring wheat crops may increase by 12% to 19% in the south of Kazakhstan and by 31% to 41% in the country's north, adversely affecting yields.[99] In particular, farmers could see a 26–27% decline in spring wheat yields[6] which already constitute a fraction of those observed in more favorable climates. In the last five seasons, wheat yields in Kazakhstan varied from the low 1.01 t/ha to the high 1.28 t/ha[97]. Net of the positive impact of elevated atmospheric CO_2 levels on green biomass growth, the losses in yields could go as high as 67%.[6]

Climate warming is also expected to reduce forage and fodder yields on lowland pastures and even more so on mountainous pastures in the country's south.[5] This, in turn, is projected to bring livestock productivity down 10% by 2030 and 15 to 20% by 2050.[5]

In sum, dryland areas are especially vulnerable to the risks and impacts of climate change while at the same time offering a large potential as a carbon sink. In addition to helping address the climate problem, replenishing degraded soils' SOC stock restores soil health and function and is associated with a number of co-benefits, including higher crop yields, moisture content and biodiversity.

3. Opportunities for Carbon Farming for Kazakhstan

3.1 The Concept of Carbon Farming

Soil degradation is directly associated with a loss of SOC. A declining SOC pool is a major cause and consequence of, and a reliable proxy for, soil degradation (Figure 7).[100] Degraded lands are essentially a half-empty carbon reservoir and for this reason present an especially strong sequestration potential, which UNCCD describes as 'huge.'[101] An increase in the SOC pool reverses soil degradation, improves soil health and productivity, and generally benefits the entire ecosystem of which it is a part (Figure 8). The UNCCD highlights that 'increasing SOC has crucial positive benefits for achieving LDN, climate change adaptation-mitigation, food security and the protection of biodiversity.'[101]

Land management practices at farm level, which either increase the amount of atmospheric carbon sequestered (i.e., captured and stored) by soils or plant biomass or reduce GHG (primarily, CO_2, N_2O and CH_4) emissions from land-based activities is a key dimension of **carbon farming** (whereby farming refers to an organised way of operating a piece of land to grow crops and raise livestock or both[102]). Understood more broadly, carbon farming may refer to management of carbon pools, flows and GHG fluxes at farm level, bringing carbon as one targeted farming product along with crops and livestock, with the purpose of mitigating climate change.[103] In this vein, carbon farming may also include management of livestock as well as land[24] and hence may involve, for instance, measures to reduce CH_4 emissions from enteric fermentation in ruminants. This publication focuses specifically on land management practices.

Closely related to carbon farming is the concept of **'conservation agriculture'** promoted by FAO and defined through its three principles: (1) minimum mechanical soil disturbance by reducing or eliminating tillage; (2) maintenance of permanent soil organic cover with crop residues and/or cover crops; (3) diversification of plant species through crop associations and crop rotation.[23] These and other practices aimed at reversing soil degradation and restoring soil health are also sometimes referred to as **'regenerative agriculture.'** World Bank Country Climate and Development Reports speak of **'climate-smart agriculture'** The term **SLM** is also widely used, in particular in the context of the UNCCD and WOCAT, to refer to 'a holistic approach to preserve all ecosystem services in long-term productive ecosystems by integrating economic, sociocultural and biophysical needs and values.'[101]

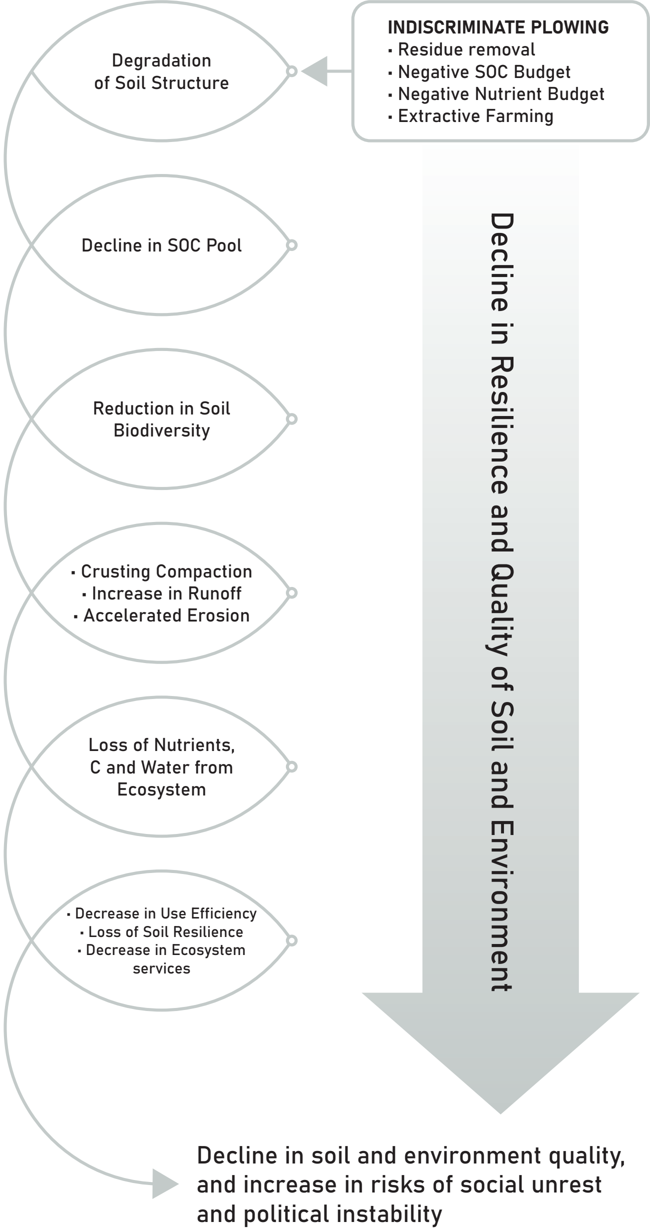


Figure 7. Consequences of SOC content decreasing as a result of excessive soil disturbance. Source: Lal (2015).

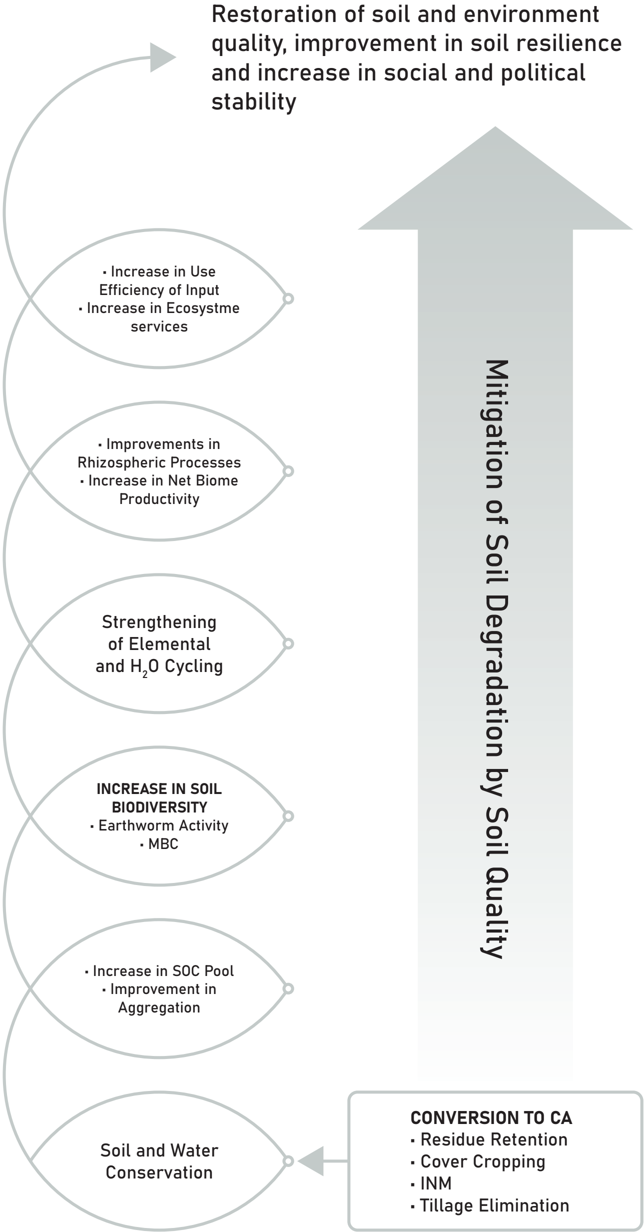


Figure 8. Improvement in soil quality as a result of an increase in SOC pool. Source: Lal (2015).

All these notions may be used to refer to the same land or livestock management practices; the term 'carbon farming,' however, emphasizes **NBS** with potential to sequester carbon or reduce/avoid emissions and replenish/preserve SOC stock.

Land-based carbon farming practices may include:[57]

On croplands:

- no-till or reduced tillage intensity;
- residue retention;
- crop rotation;
- improved crop varieties;
- cover cropping;
- agroforestry;
- crop diversification and crop associations;
- optimized use of fertilizers, organic amendments;

improved water management: drainage of waterlogged mineral soils and irrigation of crops in arid/semi-arid conditions

On grasslands:

- improved grass varieties, deep-rooting grasses;
- stocking density management in accordance with carrying capacity;
- fodder banks and fodder diversification;

Recent studies also suggest significant potential of EW, i.e., rock powder application to agricultural fields.[104]

3.2 Kazakhstan's AFOLU Sector and Its Sequestration Potential

Under the UNFCCC, parties undertook to periodically develop and publish their national inventories of anthropogenic GHG emissions by sources and removals by sinks. Emissions are reported by sectors, such as energy, industrial processes, waste, etc. The AFOLU sector comprises GHG emissions from land use, land use change, forestry and agriculture. Agriculture covers CH_4 emissions from livestock (enteric fermentation); CH_4 and N_2O emissions from manure management; CO_2 emissions from urea application and liming; emissions from biomass burning and non-CO_2 emissions from agricultural soils (direct and indirect N_2O emissions, rice cultivation).

Box 3.1 The Role of AFOLU Sector in the GHG Emissions and in the Carbon Cycle

The IPCC 5th Assessment Report thus describes the role of AFOLU in the GHG emissions and in the carbon cycle[105] (Figure 9):

"AFOLU plays a central role for food security and sustainable development … . Plants take up carbon dioxide (CO_2) from the atmosphere and nitrogen (N) from the soil when they grow, re-distributing it among different pools, including above and below-ground living biomass, dead residues, and soil organic matter. The CO_2 and other non-CO_2 GHG, largely methane (CH_4) and nitrous oxide (N_2O), are in turn released to the atmosphere by plant respiration, by decomposition of dead plant biomass and soil organic matter, and by combustion … . Anthropogenic land-use activities (e.g., management of croplands, forests, grasslands, wetlands), and changes in land use / cover (e.g., conversion of forest lands and grasslands to cropland and pasture, afforestation) cause changes superimposed on these natural fluxes. AFOLU activities lead to both sources of CO_2 (e. g., deforestation, peatland drainage) and sinks of CO_2 (e.g., afforestation, management for soil carbon sequestration), and to non-CO_2 emissions primarily from agriculture (e.g., CH_4 from livestock and rice cultivation, N_2O from manure storage and agricultural soils and biomass burning … ."

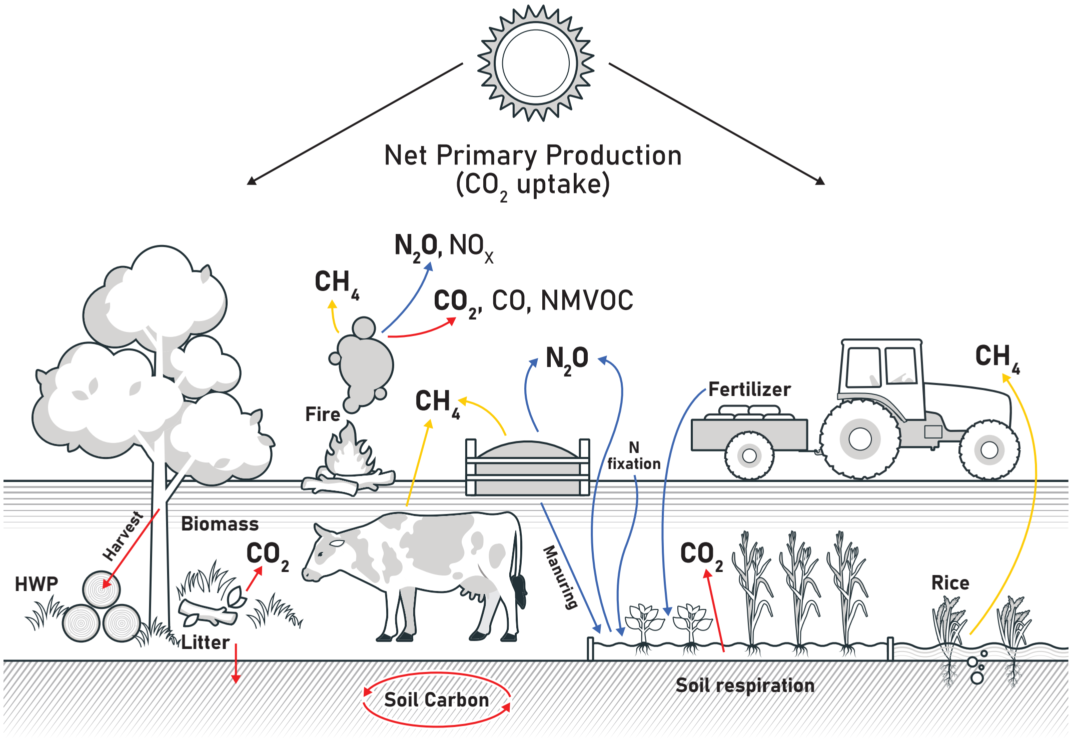


Figure 9. The main greenhouse gas emission sources/removals and processes in managed ecosystems.
Source: IPCC (2006).

In Kazakhstan, GHG emissions from croplands currently outweigh removals by forests and grasslands, making the country's LULUCF sector (and even more so, the integrated AFOLU) a net source (Figure 10). Kazakhstan's agriculture also falls in the middle range of emission intensity, which is below that for Central Asia but above the average for the OECD (Figure 11). Kazakhstan's Eighth National Communication to the UNFCCC singles out the loss of humus, i.e., SOC, as the principal reason for high emissions per hectare of croplands and points to a 'very large' potential for mitigation in this area, in the order of up to 35 Mt CO_2-equivalent per year, which is slightly in excess of its current 32 Mt CO_2 per year emission level.[5] A recent study estimates the technical potential of sequestration activities in Kazakhstan's agricultural sector to reach as much as 535 Mt CO_2 per year with 141 Mt CO_2 per year (or 40% of the country's current annual net emissions of 351 MtCO2e[5]) achievable at less than US$ 100/tCO_2e. A bulk of this cost-effective potential comes from agroforestry (93 MtCO_2e) and the adoption of carbon sequestration practices on croplands (18 MtCO_2e) and grasslands (23 MtCO_2e).[183]

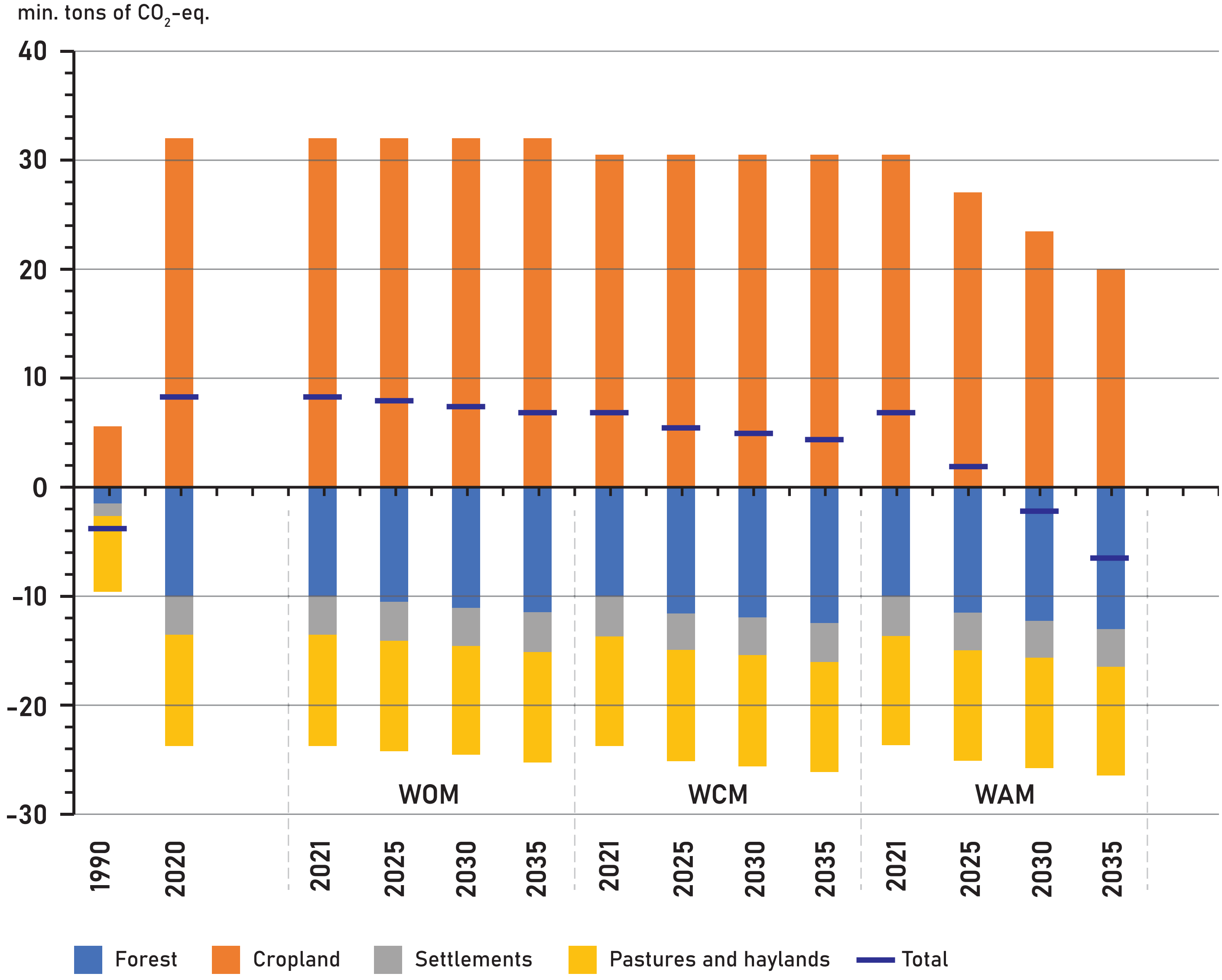


Figure 10. Kazakhstan's LULUCEF. Historical data and three alternative future scenarios: WOM – Scenario without measures; WCM — Scenario with current measures; WAM — Scenario with additional measures.
Source: Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, United Nations Development Programme in Kazakhstan, & Global Environmental Facility (2022).

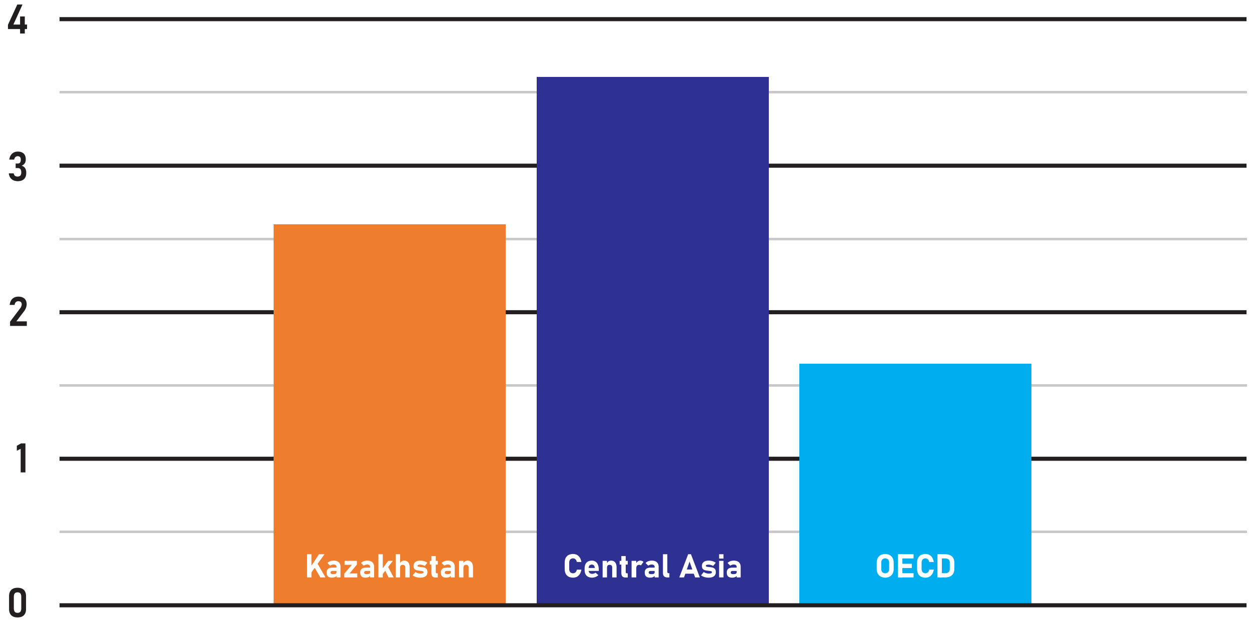


Figure 11. Agriculture emissions to agriculture GDP ratios in 2016, tCO2-eq/1000 US$ (constant 2010; based on FAOSTAT and World Bank data). Source: Santos (2019), Polo et al. (2022).

As tilling is often seen as the principal driver of SOC loss,[109] reduced tillage addresses a major cause of soil erosion. Land degradation in Central Asia countries is largely attributed to intensive tilling both in irrigated and rain-fed areas.[27] Although the magnitude and even the direction of the effect of no-till farming on carbon sequestration in soil is region- and site-specific, in dryland regions, no-till is likely to boost SOC stocks and (in drier areas) increase crop yields while also retaining soil moisture.[27]

FAO reported improvements in soil moisture after adoption of no-till in Northern Kazakhstan, leading to 20 to 60% higher wheat yields.[110] Modelling showed that the adoption of no-till along with crop rotation, cover cropping, residue retention, and direct sowing on crop fields in the Almaty region of Kazakhstan may bring about an annual SOC stock gain of around 1.14% as opposed to an annual loss of 0.74% in the BAU (conventional tillage) scenario.[111,112]

Integration of crop rotation (wheat-legume) has been shown to increase SOC, reduce soil compaction, and improve water infiltration in Central Asia countries.[27] Crop residue retention in combination with no-till was reported to increase soil moisture and decrease evaporation by a third; this approach also increased water infiltration and crop yield by 15% with a stronger effect in drier conditions.[27] In combination with no-till, soil mulching can be especially effective to reduce soil salinity.[27]

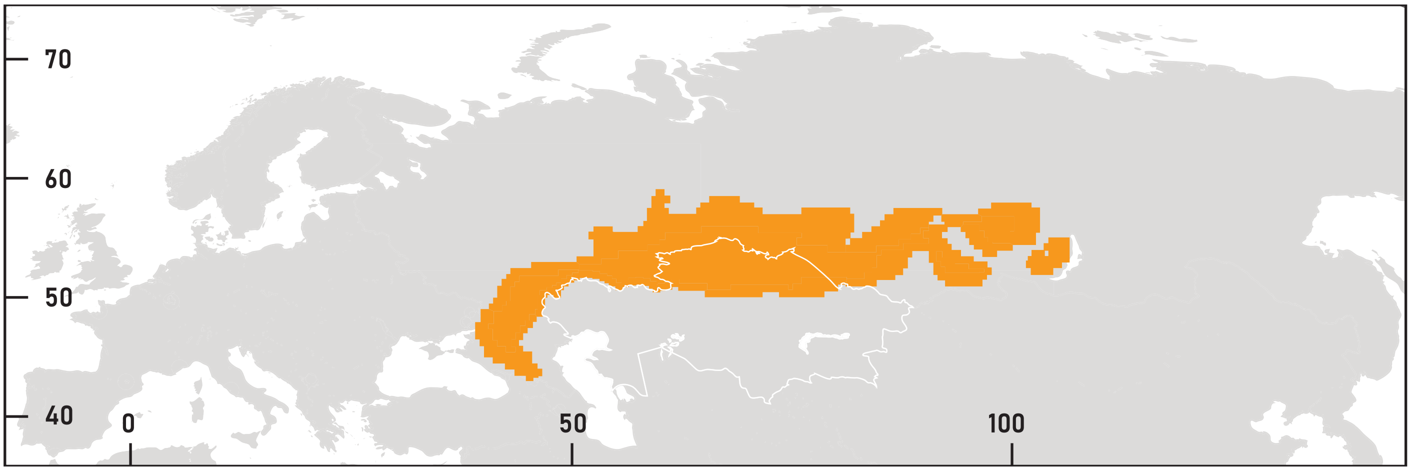


Figure 12. Virgin Lands Campaign area. Source: Rolinski et al. (2021).

Carbon farming may be especially relevant for those regions in Northern Kazakhstan where the large-scale grassland to cropland conversion program of the 1950-1960s known as the Virgin Lands Campaign (Figure 12) resulted in massive SOC losses with some estimations going as high as 45% losses in the upper 10 cm layer and 25% losses in the 100 cm layer. Before being abandoned in the 1990s, croplands in that region had their SOC stock on the verge of depletion (Figure 13), but are estimated to have gained in excess of 0.5 kgC/m^2 (or 1.8 tCO$_2$/ha) to 2010, while the full recovery will take a few decades to a hundred years, depending on soil type. Croplands which remained croplands, however, continued losing SOC.[21,113,114,115] These outcomes emphasize the importance of selecting farming techniques which would enable viable agricultural production without compromising SOC stocks on existing croplands and on abandoned lands if they are to be recultivated.[21] In particular, crop rotations with pulses have been proposed for Northern Kazakhstan to increase yields and soil fertility, reduce disease infection, and pest infestation rates.[27,116]

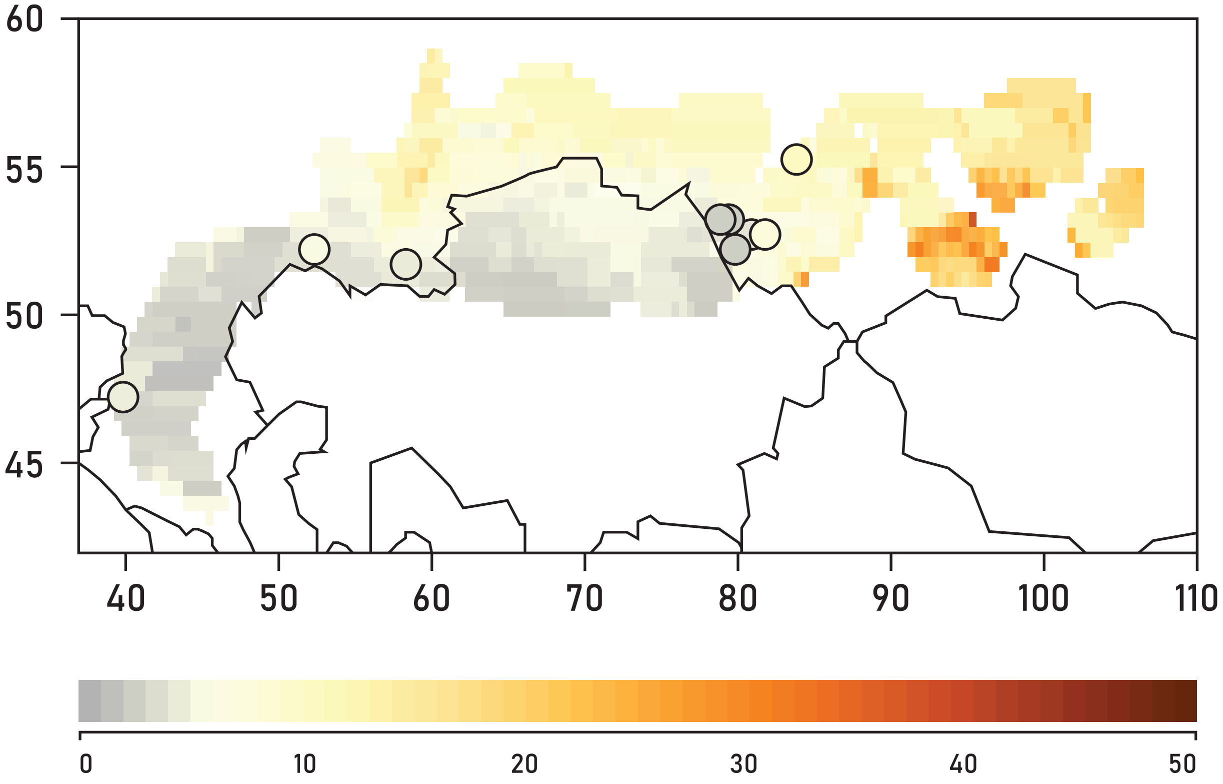


Figure 13. Modelled (colored areas) and measured (dots) average SOC stocks in kg C/m2 in the 20 cm upper layer, 1985–1995.
Source: Rolinski et al. (2021).

Deployment of agroforestry systems, such as alley cropping, field windbreaks (shelterbelts) and riparian buffers, is another viable option for the drylands belt region and, in particular, Kazakhstan. Agroforestry generally refers to the integration of trees or shrubs into a crop or livestock farming system which may increase agricultural yields as well as reduce soil erosion and improve soil health.[117] For example, alley cropping consists in an agroforestry arrangement where crops are grown in-between rows of trees or shrubs (Figure 14), which are regularly pruned to manage solarization and competition with the crops. Field windbreaks, or shelterbelts, on the other hand, are protective belts of trees or shrubs along the perimeter of a crop field (Figure 15). Although different in their implementation, both techniques can be used to reduce water and/or wind-induced soil erosion and enhance SOC pool directly—by mitigating the impact of wind or water and collecting windblown sediment particles, and indirectly—by improving the microclimate and the soil moisture content in the protected area. In addition, alley cropping may be a viable option to improve forage/fodder supply.[27]

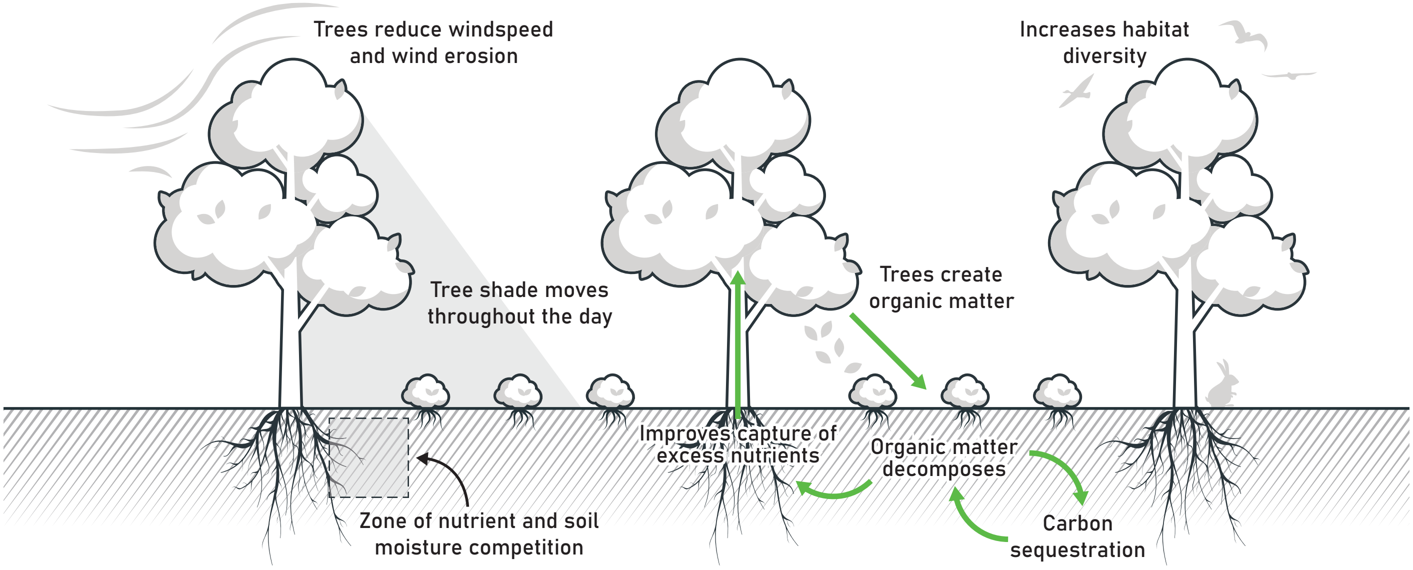


Figure 14. The operation of alley cropping.
Source: USDA (2017a).

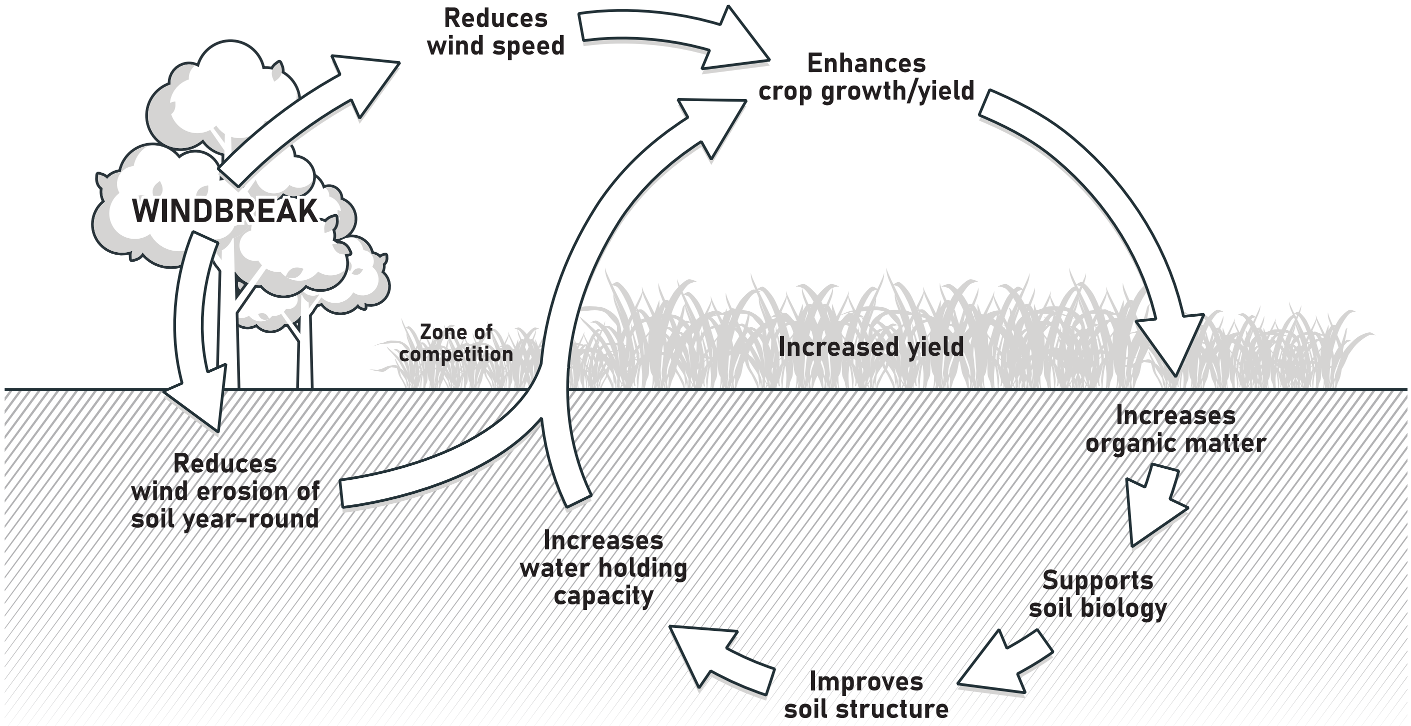


Figure 15. The operation of field windbreaks.
Source: USDA (2017b).

In dry climates, however, it is important to make sure that competition for moisture between trees or shrubs, on the one hand, and crops, on the other, is minimized so as to avoid a decline in crop yields.[119] Soil water balance is a key determinant for a number of crop management tools, including the method and timing of mowing 'in order to reduce to a minimum necessary the consumption of water at times of maximum crop need, as well as to avoid competition for nutrients.'[27]

Carbon farming also has the potential to increase crop yields. Significant yield gains can be obtained, for example, from windbreak systems in arid and semiarid climates, including in Kazakhstan, with productivity increasing by a third or even two-fold as compared to open field systems.[120,247,66,69] More recently, one-row poplar windbreaks were found to offer economic gains to farmers growing cotton, rice, barley, corn and alfalfa (lucerne), in particular on account of improved water productivity[121] as well as the marketability of poplar wood.[120]

Critical area planting is another technique used to remedy and contain progression of soil erosion and consists in establishing permanent vegetative cover on eroded land. The practice can be applied on eroded banks and shorelines or, generally, on degraded lands.[122] The planting of vegetation on sites that resist vegetation growth under normal conditions increases SOC and plant carbon stock.

Although costly at present with the current cost projections being in the range of US$ 100-200/ tCO2e.[14] EW has recently been estimated to have significant carbon sequestration potential along with co-benefits for agricultural production. One study found in particular that application of basalt rock powder on alkaline soils (such as, for example, the salinized soils of the Aral sea-bed) on which potato (solanum tuberosum) is grown may sequester in excess of 1.83 and 4.48 t CO_2/ha over a 1- and 5-year span, respectively, while improving potato growth and yield (6%) and significantly reducing nitrogen leaching.[104] Crushed rocks spread on an agricultural field enrich it with a range of minerals, including calcium, potassium and magnesium, thus improving soil health and quality.

Another study compared the effects of ground basalt application for four years in the Midwest US to a maize/soybean crop rotation system, on the one hand, and to a miscanthus plantation, on the other. While EW was found to have resulted in a 23 to 42% (1.02 t/ha per year) lower carbon loss in the maize/soybean system, it turned the miscanthus field in a carbon sink capturing 0.63–1.29 tC/ha per year.[124]

Kazakhstan is the leader in implementing conservation agriculture practices in Central Asia and is among the top adopters globally[26] with 3 Mha converted to conservation farming as of 2018—not least thanks to government subsidies which have been paid out for adopting conservation agriculture methods since 2008.[27] The Landscape Restoration Project funded by the International Bank for Reconstruction and Development's GEF as part of the Resilient Landscapes in Central Asia (Resiland CA+) program is currently being implemented in Kyzylorda and Zhambul oblasts of Kazakhstan. The project provides, in particular, for afforestation of a pilot site with saxaul trees in the dried-out part of the Aral Sea Basin near Kyzylorda and deployment of several agroforestry demonstration plots in the two oblasts, which will combine forestry with crop farming and livestock production.[28]

While Kazakhstan is a world leader in adopting conservation agriculture, conservation practices currently cover as little as 1% of the country's agricultural lands[30] or about a third of croplands that may potentially be included in scope.[107] Along with pasture improvement, conservation agriculture on crop fields has been estimated to present the largest mitigation potential (3.9 MtCO2e per year and 2.3 MtCO2e per year, respectively) compared to other conservation practices, such as the use of wind-empowered water pumps (provided that the risk of over-exploitation of water resources is properly addressed), small dams, drip irrigation, improved field machinery, precision agriculture, improved greenhouses, among others.[107]

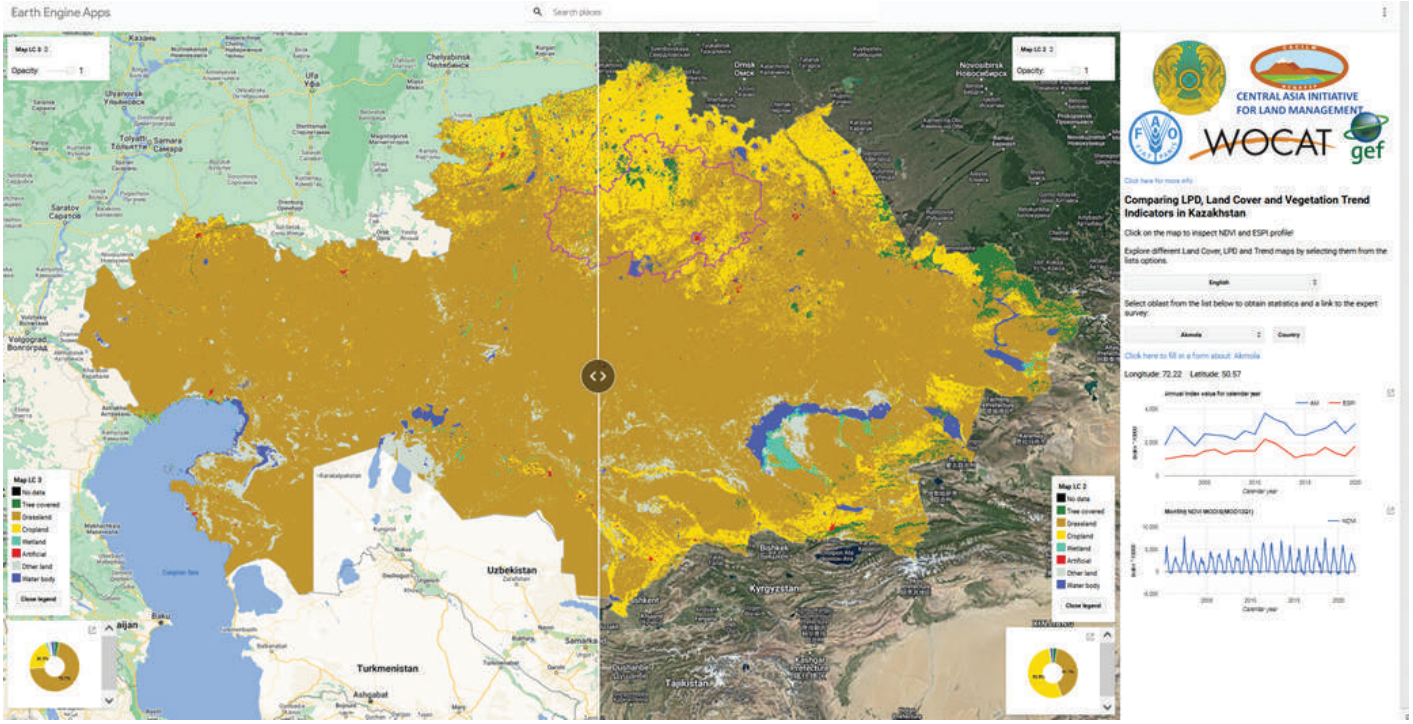
Kazakhstan's Carbon Neutrality Strategy to 2060 provides for use of cover crops, deployment of agroforestry systems integrating crop farming and animal husbandry, and generally, the scaling-up of climate-smart agriculture, including carbon farming.[30] The carbon sequestration effect could be significantly enhanced by expanding the range of measures and the land area affected. Depleted lands with major SOC losses present an especially large potential in terms of carbon sequestration and SOC stock replenishment. Degraded rangelands, which are estimated to constitute from 20% to 60% of pastures depending on the region, may become a powerful carbon removal vehicle, if the right land management practices are applied. Grasslands in areas which are most vulnerable to climate change and prone to yield declines may be used as test sites for carbon farming practices. One potential candidate is the Assy plateau in the south of Almaty oblast, whose pastures are projected to lose 42% of their current productivity by 2050.[5]

This equally applies to croplands which, as was shown in the chapters above, may offer sequestration rates in line with the 4 per 1000 target. The Virgin Lands of the country's north, which had lost much of their SOC stock, may provide an excellent opportunity to gauge the effect of carbon farming on crop fields.

Box 3.2: Tools to Assess Carbon Sequestration Potential of Advancing Sustainable Land Management Practices in Kazakhstan

The linkage of the WOCAT Global SLM Database with the Carbon Benefit Project tools enables users to assess the impact of individual technologies for carbon sequestration. The project provides tools to estimate the impact of changing land use and management activities on greenhouse gas (GHG) emissions and carbon sequestration (net GHG balance) and can be used to estimate the carbon sequestration potential of SLM practices in comparison to BAU practices.

To assess Land Degradation hotspots, WOCAT and its partners utilize Google Earth Engine applications to create customized Maps and Models tailored to specific country conditions such as Kazakhstan (Figure 16). This approach facilitates the analysis of global, national, and local maps, contributing to a more comprehensive understanding of Land Degradation processes across different scales and support the integration of indicators that support the scaling-up of SLM and achieving national LDN targets. This enhanced understanding also can help prioritize areas for the effective implementation of carbon farming and the establishment of testing centres or pilot research.



Comparing LPD, Land Cover and Vegetation Trend Indicators in Kazakhstan

Click on the map to inspect NDVI and ESPI profile!

Explore different Land Cover, LPD and Trend maps by selecting them from the lists options.

Select oblast from the list below to obtain statistics and a link to the expert survey:

Longitude: 72.22 Latitude: 50.57

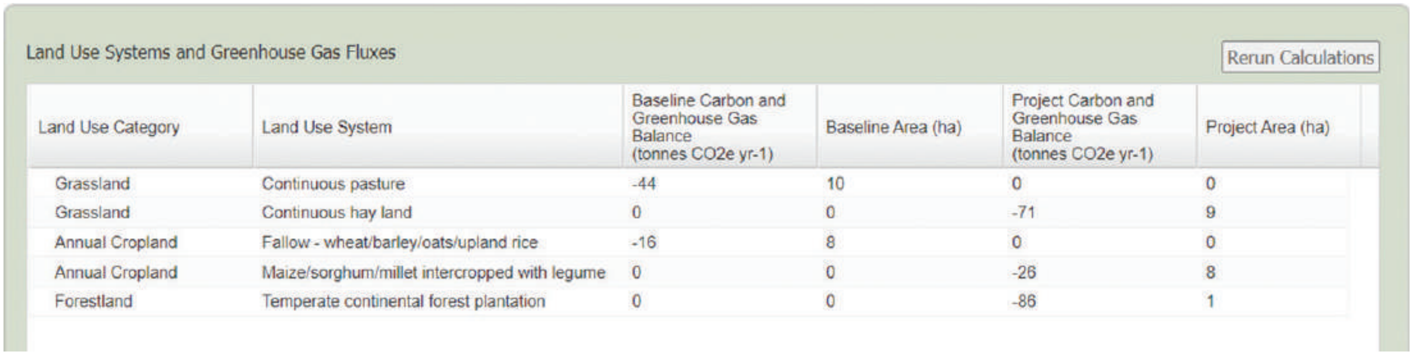
Figure 16. A screenshot of the LDN Decision Support System for Kazakhstan.
Source: WOCAT (2023b).

Box 3.3: An Example of an Application in Kazakhstan

Carbon Benefit Project tools can support a range of SLM assessments and modelling which can have important implications for initial piloting and implementation of carbon farming in Kazakhstan. For example, WOCAT applied these tools to three CALCIM II project sites to evaluate the carbon sequestration benefits of creating saxaul pasture-protective strips in the northern desert. Specifically, Svetlana in Almaty on 8 hectares, Beksultan in East-Kazakhstan on 5 hectares, and Zengi baba in Almaty region on 5 hectares:

1. **Svetlana, Almaty** was a barley field; the project introduced **a crop rotation of oats grasses and millet with no-tillage.**
2. **Beksultan, East-Kazakhstan** was degraded grassland and the project introduced **hayland planted with wheat grass.**
3. **Zengi baba, Almaty region** was also degraded grassland and the project introduced **hayland planted with wheat grass and elm seedlings on a quarter of the land.**

When all sites were considered together, the project had an estimated carbon benefit of -62 tCO2e per year, meaning it led to carbon sequestration and GHG reductions. Figure 17 shows the GHG balance for each land management strategy considered. Changing from pastureland to wheat grass hayland increased carbon sequestration in the project grasslands and appeared to be a better strategy to increase carbon in soils than activities on the croplands. In the croplands, the project crop rotation with no-till also increased carbon sequestration in soils but this had to be set against an increase in nitrogen emissions from introducing nitrogen fertilizers.



Land Use Systems and Greenhouse Gas Fluxes

Land Use Category	Land Use System	Baseline Carbon and Greenhouse Gas Balance (tonnes CO2e yr-1)	Baseline Area (ha)	Project Carbon and Greenhouse Gas Balance (tonnes CO2e yr-1)	Project Area (ha)
Grassland	Continuous pasture	-44	10	0	0
Grassland	Continuous hay land	0	0	-71	9
Annual Cropland	Fallow - wheat/barley/oats/upland rice	-16	8	0	0
Annual Cropland	Maize/sorghum/millet intercropped with legume	0	0	-26	8
Forestland	Temperate continental forest plantation	0	0	-86	1

Figure 17. A screenshot illustrating calculations of greenhouse gas gluxes in the project area – Carbon Benefit Project tools output table. Source: WOCAT (2023b).

Box 3.4. Case Study of Carbon Sequestration and GHG Reduction Benefits from SLM Practices

In the Katon-Karagay village region, overstocked livestock pastures and degraded soil and vegetation led to significant environmental challenges. To address this, the "Organization of Katon-Karagay Village Pasture Management to Minimize Land Degradation" Project, supported by grants from GEF Small Grants Programme of approximately US$ 31,420, implemented a pasture improvement technology[128]. This involved planting perennial legumes (such as sainfoin and lucerne), cereals (like smooth brome and orchard grass), and mixed grasses, alongside creating seed banks.

The introduction of this technology boosted pasture productivity, enhancing livestock quality and weight. Fodder yields were shown to have doubled which subsequently increased the incomes of local communities by 20 to 50%.[32] Approximately 80 hectares of land surrounding Katon-Karagay village, previously heavily grazed, were revitalized using this approach whereby land users carried the cost of sowing sainfoin seeds at cost of approximately $50 per hectare.[32] Sainfoin legume is highly palatable for livestock and has a deep-root system which is known to restore fertility to arable lands. Since restoring pastures and enhancing pasture productivity in Katon Karajay village was successfully achieved by planting perennial legumes, cereals and grasses and thereby creating seed banks this technology has the potential to be out and up scaled to other areas in the region. The key objective was to restore the degraded area for use as a pasture, ensure seed production of perennial grasses and cereals for further restoration, and enhance pasture productivity in other regions.

Implementation included activities like fencing to protect crops from livestock, soil processing (ploughing and harrowing), and sowing cover crops followed by perennial grasses and cereals. The harvested seeds served as a resource for restoring pastures in other areas. This SLM Technology improves the ecological health of the semi-arid Katon-Karagay region, located within a natural park, co-benefiting carbon sequestration and greenhouse gas reduction.

Figure 18. Mowed grasses after re-sowing degraded pasture areas with different legume and grass species in East Kazakhstan.
Source: WOCAT (photo: K Pachikin).

3.3 Biological Sequestration as a Sector of a Bioeconomy. Biomass and its Industrial Applications

Carbon farming implemented at scale will produce significant amounts of biomass. Its utilization as feedstock in industrial production processes can provide the foundation of a circular bioeconomy. The by now traditional application of biomass is for energy production. There is a variety of technologies that are being used or experimented with, including the production of biofuels, co-firing, torrefaction and others.

As mentioned above, the production of 'conventional' (first-generation) biofuels, i.e., those produced directly from food or feed crops (e.g., cereals, sugar and starch crops, oil crops), is associated with risks of GHG emissions related to LUC and ILUC as well as risks for food security due to competition for land with crops used for food and feed production. For this reason, limitations are being imposed on the role of conventional biofuels in climate change mitigation policies with more emphasis being placed on advanced (or 'second-generation') biofuels produced from a variety of more sustainable feedstock, including forest and agricultural residues and waste as well as less demanding energy crops that can be grown on degraded lands. For instance, the EU Renewable Energy Directive (RED II) establishes a 7% cap on the share of renewable energy in the transport sector from conventional biofuels and bioliquids in 2030. From 2030, conventional biofuels and bioliquids associated with a significant expansion of the production area into land with high carbon stock and with a high ILUC risk cannot be counted toward the EU mandatory target share of energy from renewable sources in the energy mix.[129]

A 2019 report by the International Renewable Energy Agency identifies four groups of biofuel production technologies:[130]

1. microbial conversion of lignocellulosic biomass to bioethanol or biobutanol;
2. transesterification of sustainably sourced fatty acids and methyl esters, i.e. biodiesel;
3. hydrotreatment of sustainably sourced vegetable oils or animal fats followed by alkane isomerisation and cracking to produce drop-in fuels (i.e. fuels that equal or surpass fossil fuel quality specifications and can use the existing pipeline infrastructure);
4. thermochemical pathways starting with pyrolysis to produce biocrude or gasification of biomass for syngas.

The report notes that the processes 1 and 4 have the advantage of using low quality, low cost and abundant residues feedstock but are still under active technological development, while processes 2 and 3 are mature enough for commercial operation.[130]

Another energy application of biomass is co-firing, i.e., the combustion of biomass and fossil fuels in the same power plant. Biomass can be mixed with coal before burning or be burnt in separate burners. The reason for mixing the two types of feedstock in a coal-fired power plant is that its efficiency is much higher than that of a dedicated biomass power plant.[131] By using less fossil fuels to produce more energy, co-firing is a viable transitional option to reduce emissions from power generation.[131]

The torrefaction industry has been gaining traction in recent years with first industrial-scale plants being constructed in different countries of the world. Torrefaction is thermal treatment of biomass at temperatures of 180°C to 350°C in an oxygen-deficient atmosphere for a limited period of time of ~30 minutes to ~2 hours and is sometimes referred to as 'mild pyrolysis.'[132,133] Torrefied biomass has higher energy density and is therefore a more efficient as energy carrier and cheaper to transport.[132,133]

Non-energy applications include the manufacturing of construction materials[134] (e.g., dried reed stalks for outbuildings), extraction of proteins for food or feed purposes,[135] chemical applications[136] as well as others.

4. Economic Considerations in Trading Carbon

Kazakhstan's croplands and grasslands can be utilized to deploy nature-based carbon sequestration solutions which can make a valuable contribution to mitigating climate change and alleviating its negative impacts. Changes in land management practices are needed, which requires introducing carefully designed incentives and other measures, such as capacity development. In addition to the already existing programs in Kazakhstan aimed to facilitate SLM, trading in carbon offset credits generated through carbon farming can provide such incentives.

4.1 The Global Landscape of Carbon Markets Frameworks

In 1997, the signing of the Kyoto Protocol set a precedent for creating market-based mechanisms to reduce global GHG emissions, recognizing the capability of flexible market mechanisms to encourage cost-effective emission reductions. The Kyoto Mechanisms, critical recommendations of the Protocol, intended to facilitate investment flows for abatement projects to developing regions of the world where implementation costs are low. This was based on the premise that the benefits of emission reductions are geographically unbound thus reductions occurring in one country could be claimed through purchase by another and the overall positive impact of emission reduction does not depend on where a specific project was implemented.[137,138]

Since then, two types of carbon markets have emerged: CCMs, which predominantly trade carbon allowances, and VCMs, which trade carbon credits. Market-based mechanisms including carbon markets and carbon taxes have formed the crux of international commitment toward curbing anthropogenic GHG emissions. Firstly, they provide economic incentives for emission reductions for private entities. Secondly, they may serve as a source of finance to increase investment flows into new CDR or CCS innovations and technologies. Thirdly, market-based mechanisms encourage firms to seek cost-effective solutions to reduce emissions. In addition, several carbon markets have become a cross-cutting platform for international cooperation and trade where countries jointly regulate the level of carbon emissions.

Box 4.1. Carbon Allowances and Carbon Credits

As awareness of climate change has increased, carbon emissions have increasingly become a liability for emitters due to their negative environmental externalities. To mitigate this liability, entities can purchase carbon allowances and carbon credits, which impose a monetary cost that entities can pay to offset their liabilities. These financial instruments are essentially derivatives of carbon emissions for entities seeking to fulfil mandatory or voluntary commitments toward emission reductions. Consequently, carbon allowances and carbon credits have transformed carbon emissions into tradable commodities.

Carbon allowances and carbon credits represent distinct derivatives. Carbon allowances are permits typically associated with ETS systems and other compliance markets serving as instruments for monitoring and limiting emissions within specific industrial sectors. They remain a homogenous derivative of carbon, whereby each allowance represents a unit of carbon permissible to emit under the governance of the CCM.

Carbon allowances issued within compliance markets exclusively grant emission permits and are considered homogeneous assets, with price fluctuations primarily driven by supply and demand dynamics.

In contrast, carbon credits signify concrete actions aimed at avoiding, reducing, or removing emissions, which are then sold as certified offset credits purchased by entities and individuals to counterbalance their own emissions. Their heterogeneity means that market prices for carbon credits may vary based on several aspects such as the type of offsetting activity conducted, the location of the offsetting project, and the various externalities and co-benefits produced.

Since they are issued in compliance markets, trading of carbon allowances is often strictly regulated. For example, allowances issued in the EU ETS may only be purchased via the ETS auctions, through brokers and exchange platforms permitted to trade EU allowances, or under future contracts. Carbon credits are not as strictly regulated as caron allowances and may be traded through over-the-counter (OTC) transactions, exchanges, and brokerage platforms, or through registries of the producer or verifiers.

Compliance Carbon Markets (CCMs)

Cap-and-trade CCMs, also commonly referred to as ETSs, are markets set and governed by regional, national, or multinational jurisdictions (Figure 19). ETSs are designed to reduce emissions by regulating the quantity of emitted carbon. Under an ETS, a cap is set on the emissions that regulated entities may produce without penalty and encourage private incentives to reduce emissions wherever possible such that regulated entities remain within the total allowance set for the given jurisdiction. Carbon allowances in CCMs are standardized permits and involve stringent monitoring by the ETSs' governing bodies.

Trading Flows in CCMs

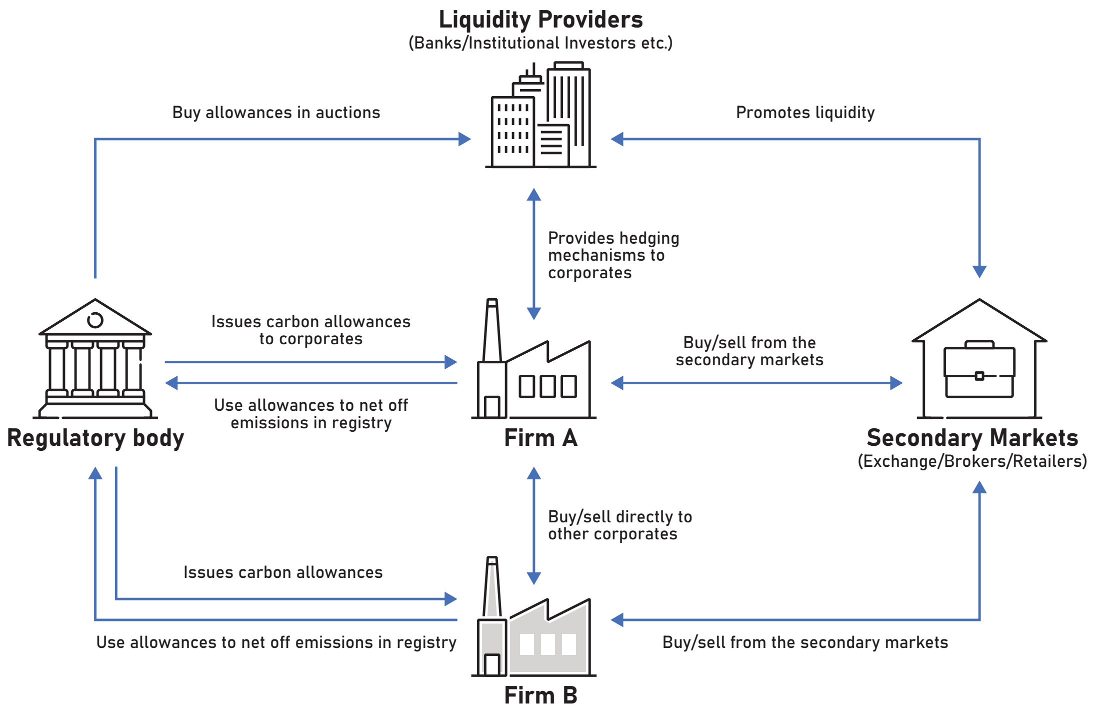


Figure 19. Illustration of compliance market flows. Source: Wellner (2014).

Governing bodies issue a fixed quantity of carbon allowances and distribute them to the ETS-regulated entities. Carbon allowances permit only a limited quota of GHGs for each legal entity, and thus set a mandatory cap on the total emissions within the regulatory boundaries of the ETS. Regulated firms with surplus allowances can trade or bank unused credits to other firms or entities unable to meet their original emissions threshold. For CCMs to make a valid contribution to global climate action, governing bodies of CCM will have to incrementally decrease the issuance of carbon allowances to their regulated entities.

Currently, there are 28 ETS in operation around the world (Figure 20). The EU ETS, the North American Western Climate Initiative, China's ETS, the US Regional Greenhouse Gas Initiative (RGGI), and the UK ETS are some of the most prominent mechanisms in terms of volume traded. The EU ETS, for example, covers almost 40% of the EU's total GHG emissions turnovers in 2021.[140,141] China's ETS is the largest in the world by volume, trading approximately 4,800 million tCO2e in 2022.[142]

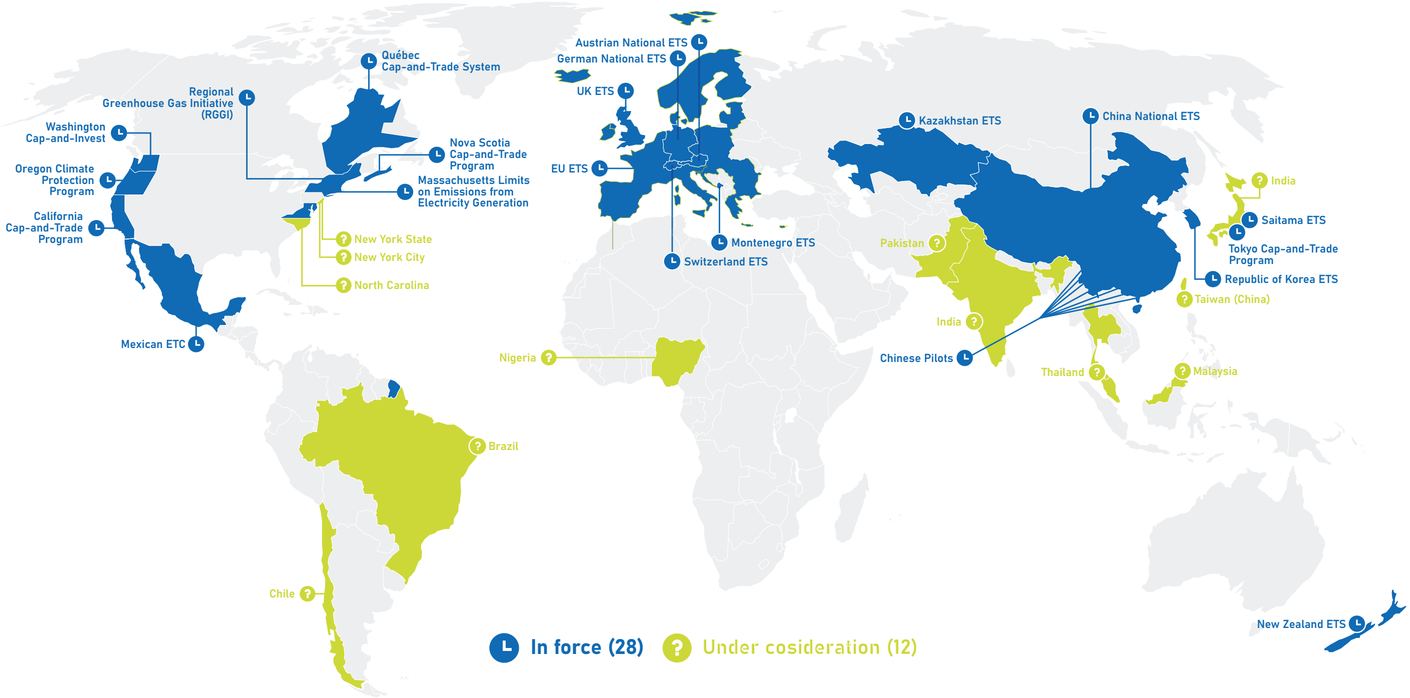
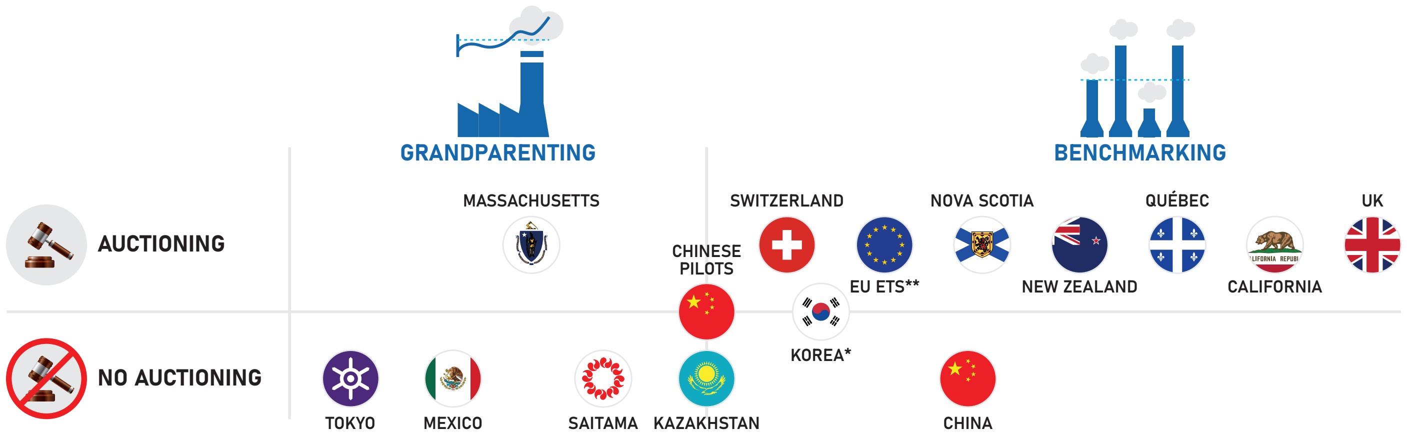


Figure 20. 28 ETSs under operation around the world as of 2023.
Source: ICAP (2023).

The initial distribution and subsequent trade of carbon allowances occurs in the primary and secondary markets of the ETS, respectively (Figure 20). Carbon allowances may be distributed by the governing bodies through a free allocation method, whereby a limited quantity of carbon allowances is allocated at zero price, or through auctioning. Free allocation may be categorized into two further methods: grandparenting or benchmarking.

Grandparenting refers to an allocation of carbon allowances based on the base-period historical emissions of a regulated entity, whereas benchmarking refers to the use of performance-based indicators to determine a sector's need for allowances. Meanwhile, auctioning under 'primary markets' refers to the initial sale of carbon allowances by the governing bodies to regulated industries and investors.

In theory, auctioning provides an equal opportunity for regulated entities to purchase carbon allowances and is a better reflection of the need for allowances within the ETS. It also generates immediate government revenue from the auctions sales. Free allocation is seen as a compensatory tool for vital industries with emissions-intensive production, such as aviation, allowing them time to implement low-emission technologies and maintaining their competitiveness. The grandparenting method of free allocation is a straightforward way of allowance distribution, however, may reward high emitters given their greater historical emissions whilst penalizing early low emitters. Benchmarking alleviates these concerns but setting of a valid benchmark requires detailed industry data and a compelling methodology.[144]



* Korean ETS uses benchmarking for cement, refinery and domestic and grandparenting for the other sectors.
** EU ETS at the current phase is using benchmarking for its free allocation sectors, while in previous phases used mainly grandparenting. Currently, RGGI is the only system that does not use free allocation: almost all permits allocated via auctioning.

Figure 21. An illustration of the various operating ETS around the world and their methods of primary distribution of carbon allowances.
Source: ICAP (2021a).

Several ETS frameworks around the world apply a combination of free allocation and auctioning of carbon allowances depending on the industries therein (Figure 21). The EU ETS currently uses both free allocation and auctioning but will phase out all free allocations by 2026 in line with the implementation of CBAM.[145] The UK also applies both auctions and free allocations, with aviation and power generation infrastructures as well as new ETS entrants being exempt from auctions.[146]

Once carbon allowances are distributed to entities, they may be traded by the carbon allowance holders to various other entities under a secondary market.[147] Secondary markets are more commercial than primary markets and thus may fulfil the price signaling function.[147] They allow entities under ETS obligations to exchange surplus allowances with those who need to compensate for their deficits. Secondary trades occurring in ETS systems such as those of the UK and EU allow non-regulated firms access to attain carbon allowances, for example, as an investment or to reach their own emission reduction targets.

ETS regulators may impose further supervision on the trading of carbon allowances in secondary markets, for example, by requiring licensing or registration from buyers of carbon allowances to monitor market participation. For example, the EU ETS requires registration from all ETS participants including traders such that all transactions of EUAs are monitored. Similarly, the UK ETS requires regulated entities as well as traders to acquire an official account for participation in the trading of carbon allowances. The EU ETS, amongst others, also applies a unique serial number to each allowance for improved traceability. Such practices would also be valuable in monitoring the production and trading of carbon credits and prevent uncertainties on ownership or double counting (see chapter 5.4).

Box 4.2: An Overview of KAZ ETS

Kazakhstan's ETS (KAZ ETS) was established in 2013.[148] In its first phase from 2013 to 2014, KAZ ETS provided carbon allowances based on free allocation using the grandparenting method, based on emissions data of 2010. In its second phase from 2014 to 2015, the grandparenting method allocated the allowances at the level that was 1.5% below the 2012 average emissions. A reserve of 20.5 million ton of CO_2 was also created, to be released by the ETS in case of new entrants. Following a short suspension, the ETS was relaunched in its third phase from 2018 to 2020 whereby entities were able to choose between a free allocation based on grandparenting or benchmarking. A reserve of 35.5 million allowances was created to account for new entrants, new emission sources, and other fluctuations. In phase four lasting for one year in 2021, KAZ ETS transitioned into benchmarking only and introduced a reserve of 11.5 million.

Under the KAZ ETS system, each entity is registered to the ETS National Carbon Quota Plan and is credited carbon allowances based on a carbon quota set by the governing body via free allocation through benchmarking. Each year, as per the Environmental Code 2021, the National Carbon Quota Plan determines the total units of carbon allowances to be distributed in the ETS including the reserve. The regulated entity is required to submit their inventory of emissions, that is, their actual emissions and removals during the reporting period to the ETS electronically. For the units of emissions produced, the entity must surrender an equivalent number of carbon allowances at the end of the reporting year.

In case the entity exceeds their carbon quota, they must compensate by purchasing additional allowances from secondary markets or face a penalty of five monthly standard units for KZT 17,250 per tCO2 (US$ 37.49) (as per 2022). In comparison, the price of carbon allowances in secondary markets of KAZ ETS is approximately KZT 563 (US$ 1.22) (as per 2022).[148,149] The ETS covers about 128 companies and the emissions cap for the year 2022-2025 is 649.8 MtCO2 for the overall period. The ETS cap for 2023 is 163.7 MtCO2 and covers entities in the regulated industries with over 20,000 tCO2 emissions per year.

Despite progress in establishing and scaling up several ETS and other CCMs (see Box 4.1) worldwide, their functioning faces some challenges. Finding an appropriate cap on the total ETS emissions is challenging for their governing bodies. Several ETS including the EU ETS have seen low prices for carbon allowances in their secondary markets due to an oversupply in the primary market. This undermined the effectiveness of these CCM caps in the early phases. Furthermore, setting more stringent caps may be counteracted with lobbying by entities with high emissions which is both difficult to detect and combat.[147] As many ETS systems do not include carbon credits generated from emission reduction, removal or abatement activities, the impact of ETS on financing innovations and technologies for emissions reductions may be limited unless the revenues generated are re-invested into such innovations and technologies by the jurisdictions.

Box 4.3. Baseline-and-Credit CCMs

The baseline-and-credit system is a form of a CCM whereby each regulated entity is set an emissions reduction mandated baseline. If an entity reduces emissions below the baseline, they receive tradeable carbon credits for the remainder of their allowance. The baseline-and-credit system aims to facilitate indirect emissions reductions and induce lower emissions through monetary incentives; however, penalties are not typically imposed if regulated entities surpass the baseline. The Canadian Technology Innovation and Emissions Reduction (TIER) Regulation is one example of the baseline-and-credit system. Implemented in 2007, it automatically applied to companies with over 100,000 tons of CO_2 emissions per year.[150]

Voluntary Carbon Markets (VCMs)

VCMs can operate independently from ETS governing bodies or jurisdictions or may be set up by governments[151] for trading carbon credits (also referred to as carbon offsets) (Box 4.1). Carbon credits are assigned a vintage year and an issuance date, whereby the vintage year refers to the year in which the emissions reduction or sequestration occurred, while the issuance date refers to the date the carbon credit was put on the market. Once a credit has been purchased for offsetting, it is retired after which it cannot be re-sold or counted again.

VCMs rely on non-obligatory participation of entities purchasing carbon credits to meet their self-defined emission reduction targets. They are decentralized systems with a high plurality of market participants including private and public entities seeking to either purchase or sell carbon credits; project developers managing the emissions reduction activities; investors, exchanges, auditors, and brokers providing transactional or financial services; and verification agencies which monitor and certify the quality of the carbon credits offered (Figure 22).

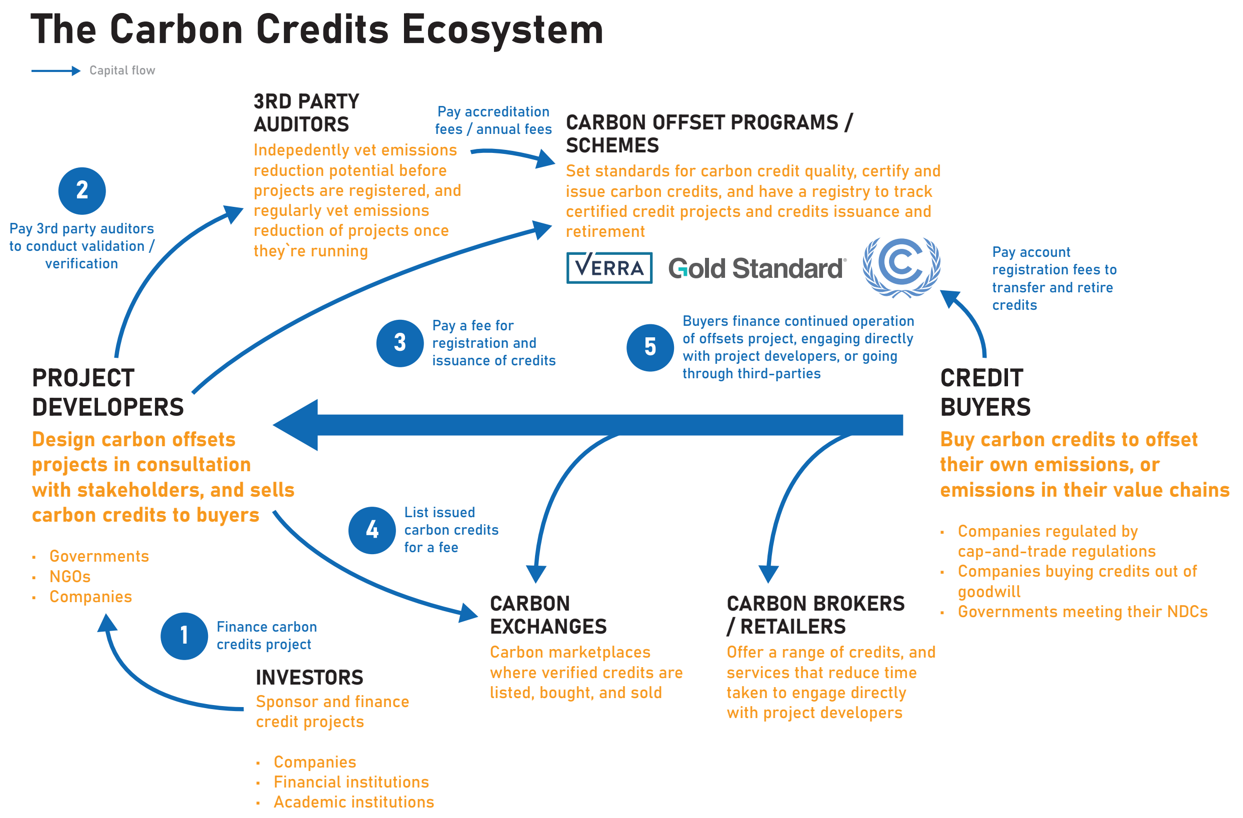


Figure 22. The Capital Flows of Carbon Credits in VCMs. Source: Paia Consulting (2021).

Map of national and subnational crediting mechanisms

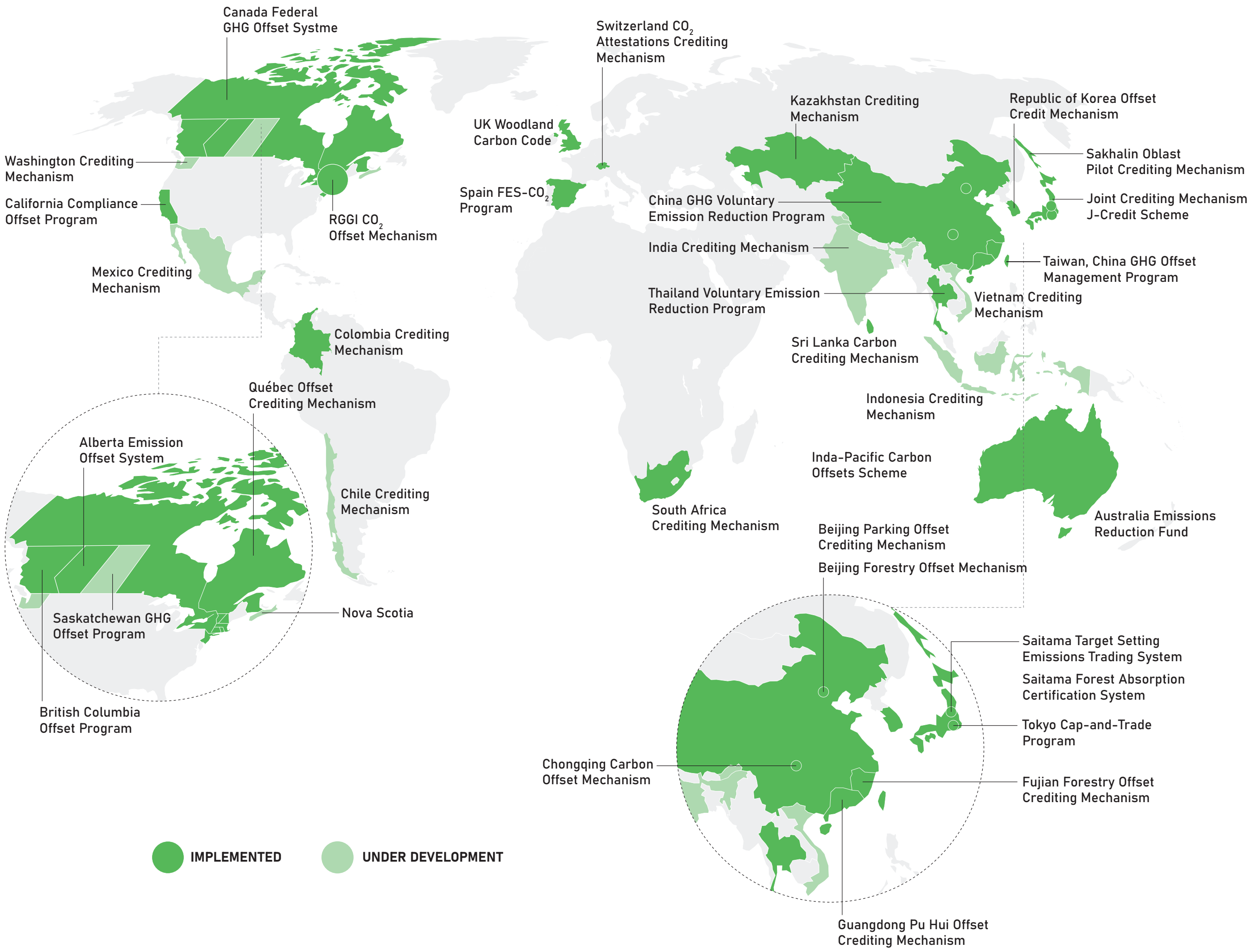


Figure 23. An illustration showing crediting mechanisms either implemented or under planning.
Source: World Bank Group (2023).

Carbon credits are typically listed on carbon registries (Box 4.4). Carbon credits produced within a certain framework may be listed for sale by the governing body of the crediting mechanism such as a specific ministry or organization overseeing their production and issuance. Credits produced by independent or international projects such as NGOs may be listed on registries with multilateral oversight such as the CDM operated by UNFCCC under the Kyoto Protocol or Article 6.4 under the Paris Agreement.[151] In some cases, verification agencies such as American Carbon Registry, Climate Action Reserve, Gold Standard, and Verra Verified Carbon Standard act as the governing bodies for their own registries since they monitor and verify the quality, quantity, and trading of credits for projects listed on their registries.

VCMs have seen a rapid acceleration of demand since the 2015 Paris Agreement (Figure 23). In 2021, total trades on all VCMs worldwide were valued at approximately US$ 2 billion;[153] therefore, the size of VCMs is still much smaller than that of CCMs estimated at US$ 850 billion in the same year.[154] However, the demand for carbon credits is likely to rise rapidly in the coming years and subsequently expand VCMs.[154] The Taskforce on Scaling Voluntary Carbon Markets estimates an increase of VCMs by a factor of 15 by 2030 and of up to 100 by 2050[150] at the global scale. Furthermore, the total market value of carbon credits can reach US$ 50 billion by 2030 if corporations seek to meet their net-zero emission ambitions.[155]

VCMs have become an essential facilitator for mobilizing finances and investments toward emission-reduction and sequestration innovations. Unlike heavily regulated CCMs, VCMs allow for small-scale pilots and prototype projects to be financed pre-emptively by private investors, and revenues from sold credits can be used to develop new technologies. They also provide greater diversity of the methods which create various co-benefits alongside emissions reductions such as restoration of peatlands or grasslands, improving biodiversity, and increasing incomes for local communities.[150,155]

On the other hand, a lack of regulation can cast doubt on the quality of carbon credits traded in VCMs. Since there is no centralized governing body guiding VCM systems, an entire industry has emerged around the verification and certification of VCM carbon credits in a bottom-up manner. This means there is no uniformity in the methodology used to rate VCM carbon credits and no unified buyer insurance against the risk of emissions reversal or leakage. For example, forest areas may be prone to natural disasters, or the prevention of deforestation in a protected area may increase its likelihood in the unprotected areas of the forest and increase risk of emissions reversals and without the knowledge of the credit owners.[156] In addition, since there is no limit on the purchase of carbon credits per entity, there is criticism that VCMs have provided a loophole for private entities to reach their emission reduction targets without actual investments into abatement technologies.[157]

Another challenge is that investors are cautious about financing new projects, often due to the lag between investment and the production of usable credits which may delay the investor's claim of emissions reductions. Co-benefits such as improvements in biodiversity or local economic development are not standardized and, therefore, difficult to measure for private certifiers. Furthermore, fraudulent operations may also deter investments. For example, carbon credit activities may not undergo robust verification assessments and quality checks before being listed on registries. Claims to carbon credits can be forged and re-sold if registries are not sufficiently monitored or if carbon credits are sold OTC. Altogether, these challenges have limited the potential supply of carbon credits in VCMs, and if not addressed, they may also reduce the growth of VCMs in the future.[158]

Lastly, unregulated VCMs have also given rise to intermediary retail traders who purchase carbon credits in bulk directly from suppliers such that they can be bundled together in portfolios and sold altogether to end buyers with earnings on commission. New exchange platforms have been developed to organize demand and supply for voluntary carbon credits. However, there is still uncertainty, particularly for corporations, around the quality and source of carbon credits, which is challenging to trace under bundled offerings.[150]

The Intersections Between Voluntary and Compliance Markets

The boundaries between CCMs and VCMs may be blurred depending on the governance of the ETS. For example, the CORSIA is an ETS which obliges airlines to offset some proportion of their emissions from international flights.[151] As per the UNFCCC, countries may also use carbon credits from across the world counting towards their NDCs.

In some ETS systems, including KAZ ETS, entities may use carbon credits to stay within their ETS cap by offsetting surplus emissions (Figure 24). Many ETS systems such as the EU ETS, New Zealand ETS (NZ ETS), and regional compliance markets previously integrated carbon credits however have since halted this practice for various reasons. Emerging ETSs such as Vietnam and Colombia are also considering allowing for the trading of carbon credits from offsets.[151] The majority of ETSs allowing carbon credits, including Kazakhstan, do so only for domestically sourced carbon credits or credits associated with linked ETS registries. Restricting to domestically sourced carbon credits provides ETS systems more control over the integrity of carbon credits used, however, it also requires greater administrative interventions and management.

Figure 24. An illustration of the ETS systems with regard to the integration of carbon credits.
Source: La Hoz Theuer et al. (2023).

The eligibility of carbon credits toward fulfilling ETS caps is defined by the regulations set by the ETS governing body. Alongside the localization of sourcing carbon credits, ETS systems may set qualitative restrictions on offsetting activities, including the type of GHG emissions, source sectors, and more; or quantitative restrictions such as a limit on the share of carbon credits counting toward the ETS cap. The UK ETS, EU ETS, and most national ETS systems within the EU including Austria and Germany prohibit the use of carbon credits for ETS obligations. Under the Chinese national ETS, entities may cover up to 5% of their obligations using CCER credits with various qualitative restrictions.

Currently, Kazakhstan imposes no quantitative restrictions on carbon credits used toward KAZ ETS obligations and allows for all domestic GHG reduction or removal activities as per the IPCC methodologies.[151] The prospect of authorities around the world re-integrating carbon credits into their compliance markets is uncertain, however, not unlikely. By imposing quality control in the production of carbon credits from carbon farming activities even at an early stage could prove advantageous as more countries seek to integrate physical offsetting activities into their ETS.

Box 4.4. Registries in Carbon Markets

Registries in carbon markets are databases which oversee the transactions and trading of carbon derivatives within specific jurisdictions or trading platforms. Registries play an important role of tracking transactions in carbon markets which increases the transparency of trade and reduces the risk of double counting.

For ETS systems, registries are typically managed by their governing body, or an independent institution appointed by the governing body, which traces the allocation and subsequent trading of carbon allowances. For example, the Union Registry is the EU ETS registry created in 2012 from the unification of individual registries of EU member states. The Union Registry requires registration from entities regulated under the ETS as well as traders seeking carbon allowances as investment opportunities and non-regulated individuals or entities seeking carbon allowances for personal use. The European Union Transaction Log automatically checks, records and authorizes all transactions between accounts in the Union Registry. EUAs may only be allocated or traded through the Union Registry accounts which ensures that each EUA is traceable. Similarly, the UK ETS also requires traders and regulated entities to register on the UK Trading Emissions Registry. The UK also operates a separate UK Kyoto Protocol Registry which records the holding and transfers of international carbon allowances.

Registries are also crucial in VCMs where the decentralized nature of demand and supply intersections make it more difficult to trace transactions for carbon credits. In VCMs, registries may be managed by private entities such as private verification agencies, non-profit organizations, and governments operating jurisdictional carbon offset projects. Majority of the current operational VCM registries require project developers to first undergo their MRV process with them or an approved independent verifying agency, which validates the quality of the offsetting activity. MRV methodologies differ based on the verification agencies. Once the project has been verified, carbon credits are issued for each unit of emissions that is avoided, reduced, or removed by the project and these credits are enlisted on the registry database.

Some registries such as the Gold Standard Impact Registry, allow buyers to purchase carbon credits directly from the registry such that the credits are retired immediately. However, other registries such as VERRA’s VCS do not allow direct transactions. Instead, buyers may purchase credits listed on VCS through licensed brokers and exchanges or directly from the project developer via an OTC transaction. In both cases, the carbon credits are then retired from the registry to prevent resale.

Currently, KAZ ETS system registry is operated by JSC Zhasyl Damu[148] and its main functions include to circulate and store carbon allowances as well as trace the transfers and exchanges of carbon allowances issued under KAZ ETS. Kazakhstan could benefit from the existing registry infrastructures by linking a national registry for the generation of carbon credits, whereby each carbon credit is issued with a unique serial number and is purchasable directly from the agencies managing carbon farming projects at the country level. Such centralization of carbon credits on one registry could streamline domestic and international demand. Alternatively, carbon credits could be listed under an international private verification agency which would increase visibility of the available credits for international buyers and investors who can then purchase the credits through a marketplace managed by Kazakhstan. However, this would require Kazakhstan’s carbon farming projects to undergo pre-determined MRV practices and methodologies set by the private verification agencies.

Global Carbon Markets and Future of Carbon Removal

Overall, both VCMs and CCMs have become critical to emission reduction strategies, and despite their limitations, both are projected to grow seismically. For example, between 2020 and 2021, carbon credits generated from Forestry and Land Use, dominated by REDD+ projects sequestration, quadrupled (and accounted for 46% of the total traded volume).[159] The EU, China, Australia, and the US have already made significant investments in their domestic emission reductions and removal activities which have the potential to supply carbon credits worldwide. Meanwhile, several countries including Brazil and India are considering implementing their own national ETS systems, which means that a significant proportion of global emissions will eventually be regulated under a carbon crediting mechanism. In addition, technologies and innovations in carbon removal and reduction activities could spur the supply of carbon credits to meet demand from rapidly advancing economies needing to curb emissions without compromising economic growth.

However, carbon removal activities under existing carbon markets are underdeveloped, underfunded, and undersupplied. IPCC estimates that at least 3.8 billion tons of permanent CO_2 removal are needed annually by 2050 to limit the global warming to 1.5C. However, the current rate of CO_2 permanently removed from the atmosphere is less than 10,000 tons.[160] There is an urgent need to scale up carbon removal activities including NBS such as soil carbon sequestration.

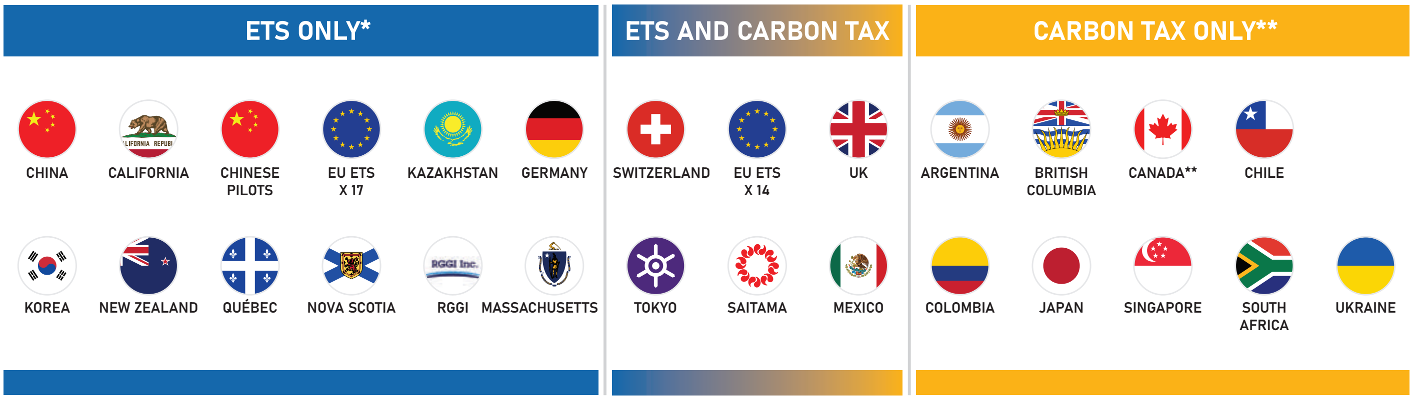
The relatively low cost of implementation and the reduced need for land space are critical advantages of carbon farming since it can utilize unusable or existing farmlands.[159] According to a World Bank report, at least 45 countries have already implemented policies or projects concerning carbon sequestration including carbon farming, SLM practices, afforestation projects, and carbon market exchanges. The number of countries participating in carbon farming is likely to grow in the coming years, however the supply of carbon credits from carbon removals overall unlikely to become saturated any time soon given the need for scaling up sequestration projects to reach the global warming target by the Paris Agreement.

Carbon Tax and Carbon Trading

A carbon or emissions tax is a policy mechanism which sets a direct penalty on emitting 1tCO2e. Carbon tax generally refers to a tax on products which are emissions intensive whereas emissions tax refers to the penalty imposed on the unit of CO_2 itself (the remaining text refers to both as carbon tax for simplicity). In theory, a carbon tax should a) internalize the social cost of emitting an additional tonne of CO_2e which would not be accounted for without policy intervention, b) increase over time to continuously incentivize investments in emissions reductions as well as represent the increased damages overtime with each additional emission, and c) be supported with reinvestment into emission reduction technologies or redistribution policies to alleviate regressive impact of the tax on low-income households.[161] To avoid undermining the competitiveness of domestic industries, jurisdictions may need to apply carbon tariffs to raise in line import prices.

Whereas ETS systems impose a cap on the quantity of emissions, a carbon tax imposes a per unit price of emitting without controlling the overall quantity of emissions. Carbon taxes may be preferred over ETS if jurisdictions are smaller and have less means to implement a sophisticated market with continuous governance needs, or, if price uncertainty, especially with low prices of carbon allowances, may deter future investments in abatement technologies. Carbon taxes may also be imposed to cover emissions not accounted for under existing ETS systems. For example, some EU countries including Denmark, Sweden, France have imposed carbon taxes in sectors which are not covered by the wider EU ETS.[162]

However, carbon taxes and ETS need not be mutually exclusive carbon crediting instruments. As of 2021, 35 different carbon taxes had been implemented in jurisdictions across the world and in many regions such as the UK, and several EU countries, carbon taxes co-exist with ETS systems to maintain a continuous robustness of the overall carbon price and emission reductions incentives (Figure 25). For example, the UK imposes a variable tax on energy providers and power infrastructure entities which omits the gap between the ETS price of carbon allowances and the country's target carbon price.



* As of 2021
** Canadian Federal "backstop" measure applied to provinces not already implementing carbon pricing. As of October 2020 this includes Alberta, Manitoba, New Brunswick, Northwest Territories, Nunavut, Ontario, Prince Edward Island, Saskatchewan, Yukon

Figure 25. An illustration representing countries which have implemented an ETS, a carbon tax, or both mechanisms.
Source: ICAP (2021b).

4.2 Carbon Farming as a Source of Temporary Carbon Removal Credits

Carbon credits sourced from emission removals (referred to as carbon removal credits in the chapter from here on) which can be further categorized into permanent or temporary removals. Though thresholds vary, permanent carbon removals are currently defined as removal or sequestration of atmospheric emissions which will not be released back into the atmosphere for at least 100 years. Geological sequestration through methods such as rock mineralization or saline aquifers, as briefly discussed in Chapter 1, is considered permanent. Permanence differs from durability of carbon removals, whereby durability assesses the risk of emissions reversal and only in a given duration of the carbon credit whereas permanence refers to the length of time the carbon remains sequestered in ideal conditions. For example, afforestation is considered permanent since trees can survive and biologically sequester carbon for over 100 years, however, forests are vulnerable to fires, storms, and deforestation which poses a risk of reversing the sequestered carbon. Hence, it is not considered durable means of sequestration.[164]

Actuating permanent sequestration to the required scale has been slow and costly. Permanent sequestration through AR activities is typically conducted at a large scale. It requires long-term commitments, which reduces participation from small-land owners or farmers. At the same time, investments and capital required for permanent geological or chemical sequestration are also highly expensive means of carbon removals. Altogether, these factors have contributed to the limited adoption of permanent sequestration.[165]

Projects which cannot guarantee permanence but can provide durability of storage over shorter time periods, such as carbon farming, can nevertheless provide a useful contribution towards combating climate change as they offer a compensatory delay for the negative impact of current emissions. In other words, they provide a buffer against surplus current emissions in anticipation of the future deployment of permanent sequestration technologies or abatement at scale.

A criticism of temporary sequestration relates to the potential negligence of permanent solutions to emission reductions. Temporary sequestration can be viewed as a deferral of emissions for future generations and thus is seen to have no impact on total emissions mitigation. On the other hand, temporary sequestration has been shown to facilitate lower emission pathways with fast implementation while providing essential streams of investments that can be utilized toward permanent forms of sequestration, as well as emission reduction and climate adaptation activities. In other words, "whenever there is a positive time value to carbon, there is a positive value to temporary capture and storage".[166]

The concept of temporary carbon credits trading was first introduced with the trading of temporary certified emissions reductions (t-CER) under the CDM. As one of the proposed Kyoto Mechanisms, CDM encouraged developed countries to implement projects in developing countries to earn carbon credits towards their own national emission reductions targets and sell excess capacities as international permits with other signatories. Since then, projects have been certified based on assumed storage periods ranging from 1 to 100 years. For example, The Verified Carbon Standard methodology under the VCM verifier Verra assigns permanence as works with periods between 30 and 100 years to follow typical tree-cutting cycles for forest-based sequestration. Carbon removal and storage methods that guarantee storage for less than 30 years (and in some cases, less than 20 years) can issue temporary carbon credits.

Temporary carbon credits are issued with an expiration date that occurs a certain period after the credit's retirement. Temporary credits are often not fungible with more permanent credits or reductions. Carbon removal projects may issue temporary carbon removal credits either ex-post or ex-ante. Under ex-post, credits are issued based on actual mitigation rather than expected outcomes and thus represent the net present value of mitigation attained.[15] This approach reduces the need for continuous monitoring and reversal-related risk management or liability agreements since the storage period is already consumed. From a supplier's perspective, issuing ex-post credits annually from projects such as crop rotation sequestration also provides incentives to continue sequestering for further generation income via temporary carbon credits. However, ex-post crediting could yield fewer credits on an incremental basis since the activity must be completed first. This could delay the initial investments required to incentivize temporary sequestration in the first place. With ex-ante, credits are issued based on the nominal storage period and thus allow for early investments, but consequently, require continuous monitoring and risk management of emission reversals.

Box 4.5. Ton-Year Accounting

Ton-Year Accounting is an approach to measure and compare impact of various temporary carbon sequestration activities. Due to its simplicity, ton-year accounting has gained popularity, especially for private entities trading on VCMs. The key assumption is that the product of the quantity and duration of storage defines the magnitude of the 'temporary carbon storage'. The notion of temporary carbon storage equalizes the impact of a greater volume of carbon sequestered for a shorter period with the impact of a smaller volume of carbon sequestered for a more extended period. Therefore, a 'ton-year' refers to the impact of absorbing from the atmosphere and storing 1tCO2e for one year[167] and is used as a unit in temporary carbon sequestration activities.

Calculating ton-years for the issuance of a temporary carbon removal credits requires a decision on the expected storage duration, which, once surpassed, expires the credit itself, and its benefits can no longer formally count toward climate change mitigation.[15] This alleviates the need to measure residual carbon storage beyond a realistic/typical timeframe. Time horizons for setting storage durations have been extensively developed by the IPCC 2006 guidelines and 2019 refinements, Climate Action Reserve, and the Australian Carbon Farming Initiative, amongst others, whereby global warming potentials (GWPs) are calculated by considering the total radiative forcing of emissions over a one-hundred-year period. Shorter time horizons than those based on GWPs may also be selected.[15]

Understanding the impact of temporary credits requires a comparison with permanent credits either in the physical sense of impact or in economic terms of value. Ton-year accounting approximates the surplus energy that CO_2 emissions trap into the atmosphere, also known as cumulative radiative forcing, which causes warming.[167] The concept of cumulative radiative forcing underlies the physical equivalence claims. Energy captured into the earth's climate due to atmospheric carbon is quantifiably equivalent to the energy that is avoided being captured when the carbon is sequestered or removed temporarily. This can create an accounting balance in the cumulative radiative forcing whereby the temporary sequestration can be claimed equivalent to permanent sequestration or removal. Equivalence may be overstated or understated depending on the ton-year accounting method used however the fundamental concept of physical equivalence remains.

Various ton-year accounting methods calculate differently the extent to which the cumulative radiative forcing is lessened by carbon storage. There are two main types of ton-year accounting: the Moura Costa method and the Lashoff method. Both methods assume that the temporary storage of carbon is subject to a full re-emission once the storage period is over, however, the Lashoff method also takes into consideration the possibility of the leakage of carbon within the duration of the storage. The distinction between these two methods is crucial, since the use of one or the other could drastically alter the cost of emissions, and subsequently, the value of temporary carbon storage.[167]

4.3 Key Factors to Influence Carbon Prices

As per economic theory, GHG emissions are a negative externality driving climate change and harboring social costs for third parties, which is not accounted for under the free market pricing mechanism, leading to over-consumption or overproduction of a product. In comparison, emission reduction efforts to combat climate change are a form of global public good, whereby its influence has a positive non-rivalrous, and non-excludable benefit on others, leading to many countries free-riding on the efforts of others.[168] In theory, if seen as a purely economic problem, emissions and climate change could be addressed by properly accounting for the negative consequences of emitting to be paid by the direct parties involved. This requires setting an appropriate price capturing the social cost of emitting an additional unit of emissions into the atmosphere.

In general, pricing mechanisms describe the relationships between demand and supply in any given economic market. Born out of the implicit interactions between consumers and producers, price has three crucial functions: signaling, incentivizing, and rationing. First, price signals scarcity of supply to consumers and the level of demand to producers.

Second, price changes incentivize producers and consumers to allocate preferences and resources toward or away from a product. Third, price rations scarce goods to those who can pay a higher price while increasing the distribution of abundant goods as they become affordable.

By capturing the negative externalities of emissions, carbon prices should a) signal the scarcity of emission capacity (i.e., how tight is the remaining 'carbon budget'), b) incentivize diversion of resources toward low emission-intensity products, and c) limit emissions unless it is unavoidable from the implementation of crucial industry or infrastructure. Carbon pricing must incentivize cost-effective emissions reductions by regulated entities in the short term, and in the long run, incentivize innovations in abatement.[169] The way in which a pricing mechanism achieves these goals varies depending on the instruments selected to attain a carbon price.[170]

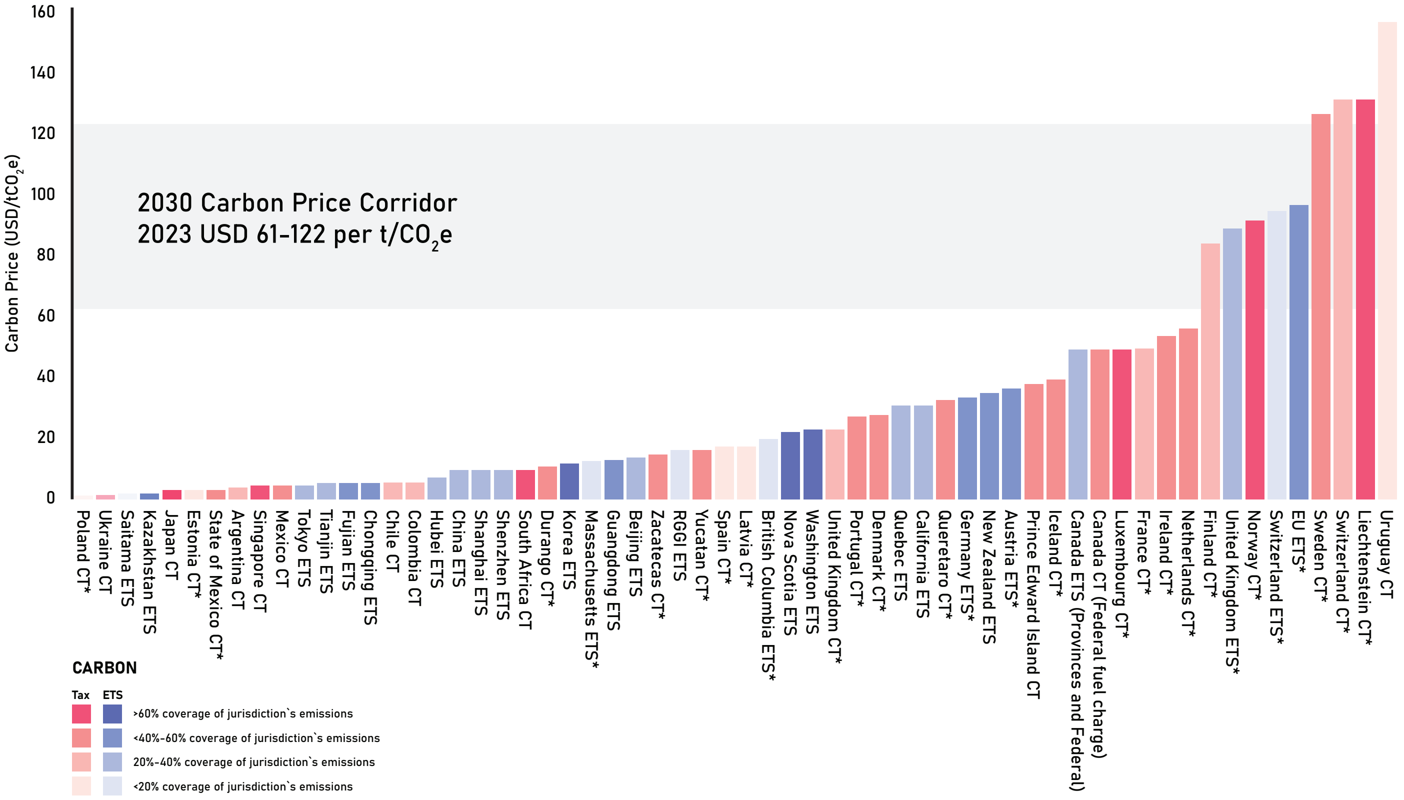
Carbon prices can be levied upstream or downstream. Upstream entities include those who introduce the unit of emissions into the economy such as energy producers, manufacturing, or mining. Downstream entities are those who consume the goods or services of which the emissions are a by-product such as households, firms, and governments. Carbon prices are often levied on mid-stream entities which intermediate supply to consumers such as energy infrastructure providers, fuel distributors, or industrial facilities. However, regardless of the imposition of carbon prices, it is ultimately passed on to the end consumers in the final product price, the extent of which is determined by their price sensitivity, i.e., elasticity of demand.[169]

The two key policy instruments for governments to influence carbon pricing are carbon taxes and ETS systems. As carbon tax defines a fixed carbon price for every unit of emission, it acts as a signaling function. The influence of carbon tax as a signal and its subsequent consequences varies depending on whether it is levied upstream on production and supply inputs such as energy production, or downstream i.e., on consumption of fossil fuels. If carbon tax is levied upstream on production such as energy generation, it increases the production cost, which, subject to various demand elasticities, ripples into rising prices of all goods and services requiring regulated inputs. The signaling function of carbon tax applied on upstream production may be lower if demand is highly inelastic as with fossil fuels. If carbon tax is levied downstream, it directly targets the demand rather than raising prices across the entire economy.[169]

Under an ETS framework, as discussed in Section 4.1, a carbon price is attained through balancing the demand and supply of carbon allowances under a cap set by the governing body of the ETS. For example, under several ETS systems such as the EU ETS, regulated entities may purchase or receive carbon allowances in the primary allocation and 'surrender' the quantity of allowances equivalent to their actual emissions at the end of each year. Should the entity be within their emissions budget, they may keep the carbon allowances for purpose in future years or sell them in secondary markets.[171] Importantly, the primary auctioning of carbon allowances, and subsequent trading of surplus allowances in secondary ETS markets, ultimately influences the price of carbon in jurisdictions with ETS systems.

Several jurisdictions have implemented carbon taxes alongside an ETS (Figure 26), however, under such systems it is important to assess the impacts or overlaps between the two policy instruments including avoiding possibilities for arbitrage, double penalties, or negative impacts on competitiveness of regulated industries both domestically and on international markets. In some cases, an ETS applies a minimum price on the carbon allowance which acts as a fixed tax on per unit of emissions produced by the regulated entity and any fluctuations above the price floor are due to the demand and supply forces for carbon allowances. Alternatively, some jurisdictions may choose to set up a carbon tax whereby the levied tax reduces if entities can offset or reduce their emissions, as is done in Singapore and South Africa (Section 4.1).

For example, although the EU sets a unified minimum carbon price through its ETS across its 27 member countries, some jurisdictions including Austria, Germany, and Sweden have implemented their own carbon tax or national ETS systems which aim to raise carbon prices at the national level. For example, Sweden's carbon tax preceded the formation of the EU ETS and to avoid double penalties, Sweden excluded industries already covered by the EU ETS from its national tax. However, since prices in the EU ETS are subject to fluctuation and have remained relatively lower per unit of emission in comparison to Sweden's carbon tax, entities covered under the Swedish carbon tax are paying a higher price.[172]



Note: Normal prices on April 1, 2023, or most recent exchange-traded or action prices before April 1, 2023, are shown for illustrative purposes only. Only the main rate is shown for each instrument. Some instruments are not shown in this graph as current price information is not available. Prices are not necessarily comparable between instruments because of (for example) differences in the sectors covered and allocation methods applied, specific exemptions, and compensation methods. The 2030 carbon price corridor is based on the recommendations in the report of the High-Level Commission on Carbon Prices adjusted for inflation. Several jurisdictions apply different carbon tax rates to different sectors or fuels. In these cases, the included price reflects the highest general tax rate or primary fuel covered by the carbon tax. The instruments included on the x-axis reflect prices provided by each instrument. Instruments indicated with * are in jurisdictions with multiple instruments, so coverage of those jurisdictions' total emissions may be higher than indicated by an individual instrument. The EU ETS includes 27 EU member states plus Norway, Iceland and Liechtenstein. Several federal and subnational policies in Canada are priced at the same rate, reflecting the Pan-Canadian Approach that requires all Canadian provinces and territories to have a carbon pricing system in place that aligns with the minimum national stringency federal standards. These are presented in to instruments (a carbon tax and an ETS): the carbon tax entry (Canada provinces and federal) includes the federal fuel charge, British Columbia carbon tax and Newfoundland and Labrador carbon tax, while Canada federal and provinces (ETS entry) includes the federal Output-Based Pricing System (OBPS), Alberta Technology Innovation Emissions Reduction regulation, New Brunswick ETS, Newfoundland and Labrador Performance Standard Systems, and Saskatchewan OBPS. The coverage under Canada reflects the combined coverage of Canada's total emissions by the included policies. Coverage estimates for subnational Mexico carbon taxes were not available – approximate estimates are included based on the fuels covered by each instrument.

Figure 26. Carbon pricing across various jurisdictions achieved either through an ETS (blue bars) or a carbon tax (red bars) whereby the intensity of the colors indicate the coverage of the jurisdiction's total emissions covered by the relevant policy.
Source: World Bank Group (2023).

Some policy instruments can be counter-productive to raising the carbon price. Most notably, subsidization of fossil fuels or other emissions-intensive activities distorts the market prices and weakens the instruments put in place to reduce emissions.[173] In 2022, worldwide subsidies for the use of and consumption of energy grew to over US$ 1 trillion, in part due to the high volatility of energy prices since sanctions were placed on Russian imports. Although energy costs in consumption are often subsidized to prevent energy and fuel poverty for low income households, such policies overtime may seriously undermine any direct instruments applied to raise carbon prices.[16] Border adjustment mechanisms such as the EU CBAM (see Box 4.10) imposes a carbon tariff on imports. By raising the price of the imports via a tariff, border adjustment mechanisms also influence a jurisdiction's overall carbon pricing in conjunction with regional policies such as a carbon tax or an ETS.[16]

The culmination of these various policy instruments contributes toward the eventual the carbon price of a jurisdiction or a carbon market with the ultimate outcome being to monetarily account, as closely as possible, the social cost of an additional unit of emissions which would otherwise be neglected under free-market forces.

VCMs may also have an impact on carbon prices, if for example, an ETS system allows the use of carbon credits in which case, the price of the carbon credit becomes the price an entity must pay for one unit of emission. However, pricing of carbon credits is even more subjugated by demand and supply forces, and the heterogeneity of carbon credits dilutes the price mechanisms for carbon.

Box 4.6. Minimum Pricing in ETS

A key challenge faced in pricing carbon through the ETS policy instrument is the risk of an over-supply of carbon allowances. For example, in its first phase, the EU ETS experienced prices close to zero since the volume of carbon allowances allocated by authorities exceeded the actual level of eventually verified emissions by approximately 2%. In its second phase, the EU ETS experienced near-zero prices again in the aftermath of the sovereign debt crisis which reduced economic activity, subsequently reducing emissions below the distributed volume of the carbon allowances. Similarly, the RGGI ETS also suffered from an oversupply of allowances which meant that prices remained as low as US\$ 2/tCO$_2$.[147,150]

To address this challenge, the EU, for example, introduced a Market Stability Reserve following an excess of supply dampening prices of allowances in the EU ETS, which automatically adjusted the volumes of allowances auctioned depending on the existing ETS supply.[174] The motivation for the introduction of this mechanism was due to steep price declines in its early phases following an oversupply in the market, significantly since the 2008 Great Recession slowed down productivity and emissions, and subsequently, the need for allowances for several industries. The UK ETS plans to implement a transitional Auction Reserve Price of GBP 22 per allowance.[146] The UK ETS and the RGGI ETS both rely on cost containment mechanisms which allows governing bodies to release carbon allowances in addition to those held in reserve to be made available when prices for verified emissions exceed a price ceiling. In fact, price floors and ceilings have been implemented in various forms in both regional and national ETS.

In addition, ETS bodies may also track registries which ensure that all allowances are consistently accounted for to prevent double counting. Such registries are important in maintaining the integrity of CCMs and allow consistent governance and transparency in the exchange of carbon allowances. Other countries have implemented a carbon price floor in their ETS to prevent carbon prices from falling to negligible costs for firms. In 2013, the UK applied a carbon price floor for energy producers in its ETS, which is pegged to the EU ETS allowance price and supplemented by a Carbon Support Price, which is added on top of the EU ETS price in case this is lower than the desired price floor. However, the UK price floor has been criticized since there is less evidence of it contributing to reducing carbon emissions while increasing energy costs for consumers.[175] In 2019, the Netherlands also considered a carbon price floor of EUR 12.30/tCO$_2$ for power generation plants regulated under their ETS, whereby a national carbon tax would top a fall in prices below the floor, although this has yet to be implemented. In 2021, the Dutch government also planned to include such a scheme in their legislation for industrial installation. For Kazakhstan, integrating carbon farming-generated credits into a domestic ETS or exchange effectively would also allow it to regulate domestic prices using tools such as a price floor.

Current Carbon Prices Around the World

About 96 of the 146 participants of the NDCs of the Paris Agreement have considered the use of carbon pricing to attain their emissions reduction ambitions. There are 40 national and 25 regional jurisdictions which have levied a price on carbon, covering in total 15% of the global GHG emissions.

In 2017, the High-Level Commission on Carbon Prices, an initiative bringing together public and private expertise on global carbon pricing, published a report stating that carbon prices must reach at least US$ 40-80/MtCO2e by 2020 and US$ 50-100/tCO2e in real terms by 2030 to limit global warming to 2^0C with complementary environmental policies.[31] The IPCC Working Group III's contribution to the Sixth Assessment Report measures the marginal abatement cost of carbon to US$ 115/tCO2 by 2030 in 2023 terms.[16] The OECD estimates carbon must be priced at US$ 147/tCO2e by 2030 to achieve net-zero emissions by 2050.[176]

However, carbon prices have remained far below the recommended levels. In 2020, carbon prices ranged from US$ 1/tCO2e to US$ 119/tCO2e, with the latter being implemented through Sweden's carbon taxes. The highest ETS-based carbon price is found in the EU ETS, at EUR 78/tCO2e, followed by the Swiss ETS.[16] In the foreseeable future, carbon prices will remain highly diverse across jurisdictions due to differences in incentives through which countries price carbon, as well as the stark variations in their national industries, economic circumstances, and political relations.[169] Several countries have planned to increase their carbon taxes in the coming years to align with their emissions reduction strategies. Canada is set to increase its carbon taxes to CAD 170 by 2030. South Africa is planning a raise its carbon tax to US$ 30 by the same year, while Singapore plans to raise its tax from SGD 5 to SGD 45 by 2026.[16]

For Kazakhstan specifically, the World Bank in its Country and Climate Development Report finds that the nation must achieve US$ 20/tCO2e by 2030 to attain half of its NDC action plan toward the Paris Agreement.[177] Currently, Kazakhstan has no specific carbon tax policy and its prices are determined through carbon allowances traded in the KAZ ETS at approximately US$ 1.10 to 1.22 per ton of CO_2.[148,178]

Box 4.7. Towards a Global Carbon Market

The fragmentation in carbon prices around the world poses a set of challenges including carbon leakages, overlapping of policies from different jurisdictions, and a failure to incentivize cost-effective mitigation. Addressing these challenges could provide a stepping-stone into furthering negotiations for possible convergences in the long run. For example, countries could set a minimum price of carbon which better reflects the social externalities of emissions. Furthermore, international support could be directed toward developing countries where capacity gaps currently limit the scope for effective carbon pricing.

Linking ETS systems can help to unify carbon prices across jurisdictions. For example, the EU ETS has been linked with the Swiss ETS and the California Cap-and-Trade Program with the Québec Cap-and-Trade System.[179] Setting a minimum price on the trading of carbon credits in various VCMs including various jurisdictional crediting mechanisms could also help to unify carbon credit prices particularly since several carbon credits are traded at significantly lower prices when compared to tax or ETS induced carbon prices.

Lastly, better coordination on carbon border adjustment schemes is needed to prevent arbitration of carbon prices. For example, the EU's CBAM exempts countries from the surcharge if they can prove payment of their embedded emissions in a country with only comparable carbon prices[180] since the EU has one of the highest carbon prices in the world.

Pricing Carbon Credits in VCMs

Carbon credits are products rather than policy instruments which means that they are priced by the producers. For carbon credits prices differ based on the heterogeneity of the credits issued and exchanged. Price differentiation in VCMs stems from the project issuing credits' implementation, impact, and quality. Primarily, the carbon avoidance, reduction, or removal activity method dramatically affects the price of the final offset credit issued.

More specifically, carbon credits may develop from a vast range of activities classified into 170 categories: from recycling or public transportation to agroforestry[159] and this diversity is evidenced in the range of pricing for carbon credits. Secondly, projects have since broadened their targets toward delivering additional benefits such as ecosystem restoration, biodiversity, or improving local well-being, adding a new dimension for pricing offsets. Contribution of credits to several high-impact SDGs can also raise their valuation.[181] Lastly, since several carbon credit verifiers emerged, those credits multiple agencies have verified are also valued strongly relative to other counterparts.

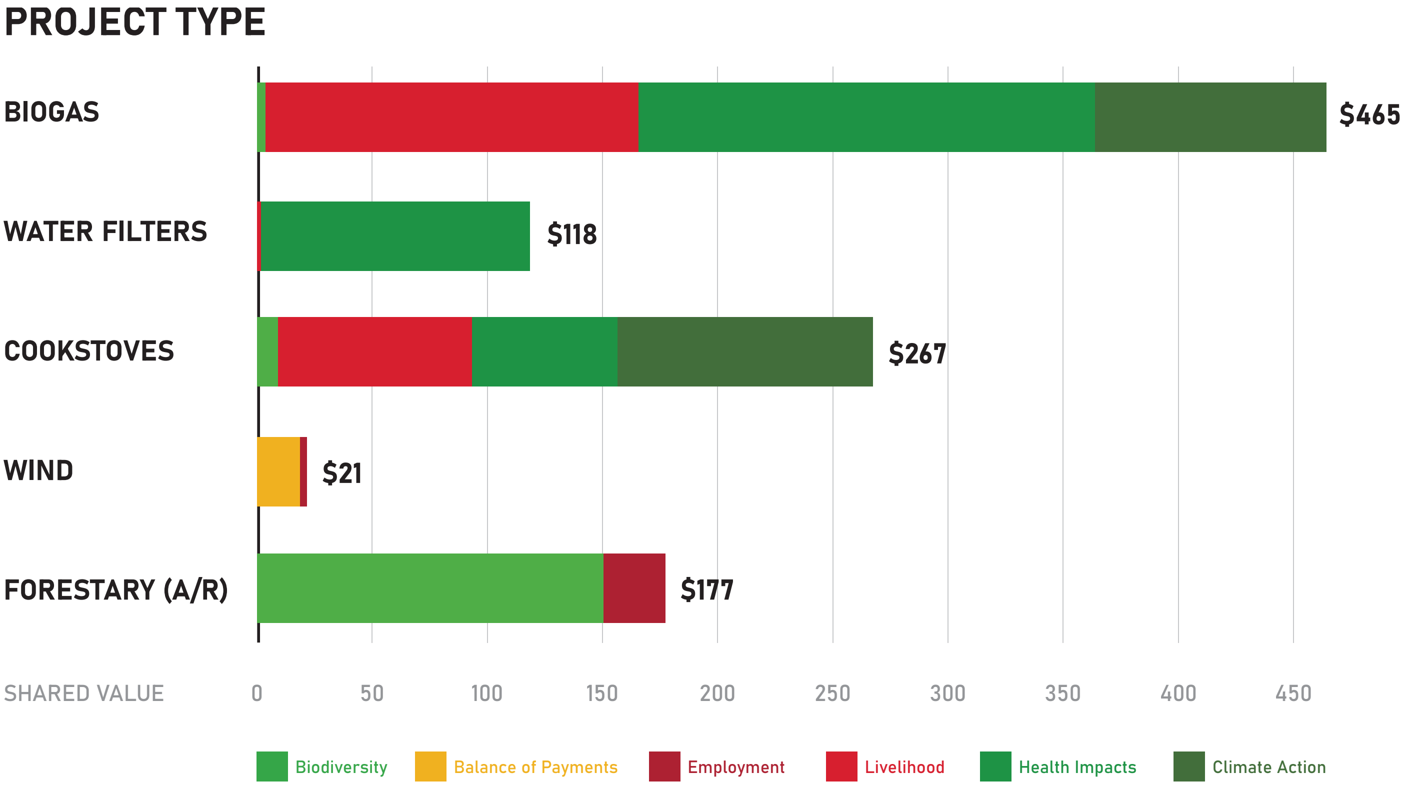


Figure 27. Monetary value of carbon credits (US$).
Source: Gold Standard (2023).

Despite their heterogeneity, carbon credits are still under price competition pressure regardless of the activity as the demand for carbon credits often does not differentiate carbon credits based on non-pricing aspects. In 2019, prices of credits generated from renewable energy projects averaged US$ 1.4/tCO2e globally, whereas forestry and land use project generated credits were on average US$ 4.3/tCO2e.[181] Meanwhile, as of 2020, the prices of removal-based carbon credits were 3 US$ higher than those with some combination of removal and reduction efforts. Agricultural carbon credits have seen prices decline from US$ 10.4/tCO2e in 2020 to 8.80 US$/tCO2e in 2021, mainly due to the influx of credits generated from livestock methane management projects. Soil carbon sequestration units were priced at US$ 30/tCO2e.[159]

Box 4.8. Price Opacity in Over-the-Counter Deals

While majority of the carbon credits generated from offsetting activities are listed on registry databases and traceable, the price at which they are bought is often less transparent. Carbon credits in VCMs are mainly purchased through OTC transactions, whereby the transaction occurs directly between the buyer and the project generating carbon credits. In such cases, the price agreed upon by the project developer and the end buyer remains undisclosed and is not reflected in the trends observed in VCM carbon prices. On the one hand, direct transactions allow projects to sell their offsets at a price which better reflects the value of the carbon credit and revenues generated may support re-investments into co-benefits. On the other hand, the price opacity coupled with the heterogeneity of carbon credits means that buyers lack a price comparison for their purchases and cannot determine the value of the carbon credit effectively.

Credits with non-carbon co-benefits were priced at a premium of US$ 4/tCO2e compared to the 2021 global E.M. Global Price Benchmark[159]. In the same year, prices for offsets from renewable energy projects were reduced due to a surge in the volume of such credits. Such credits are also cheaper since the additionality of renewable energy projects is often difficult to verify.[181] There was a decline in the price of credits over the last year, with nature-based credits experiencing a significant drop in prices from US$ 16/tCO2e to US$ 5 /tCO2e (World Bank, 2023). Future contracts imply moderate price increases in the following years. The supply of carbon credits is also set to increase as more countries look to set up emissions reduction projects and investors gain greater confidence in financing such projects In 2022, upstream investments into carbon credit generation rose by 40% compared to the previous year and new investment streams.[16]

As discussed in Chapter 3, Kazakhstan has a significant potential for carbon sequestration especially in sequestering carbon in grasses and soil matter. The country's total land-based cost-effective mitigation potential is estimated to be 0.16 GtCO2e per year (Figure 28), and the total technical mitigation potential, which refers to the maximum reduction in GHG emissions attainable through the adoption of available technologies, is just above 0.5 GtCO2e per year.[183] For comparison, the total technical mitigation potential in the entire Eastern Europe and West Central Asia (EEWA) is 1.9±0.1 GtCO2 per year, and the cost-effective mitigation potential is 0.75±0.1 GtCO2 per year, with Kazakhstan endowing the second largest sequestration potential in the region after Russia between 2024 and 2050, estimated at 4GtCO2.[183]

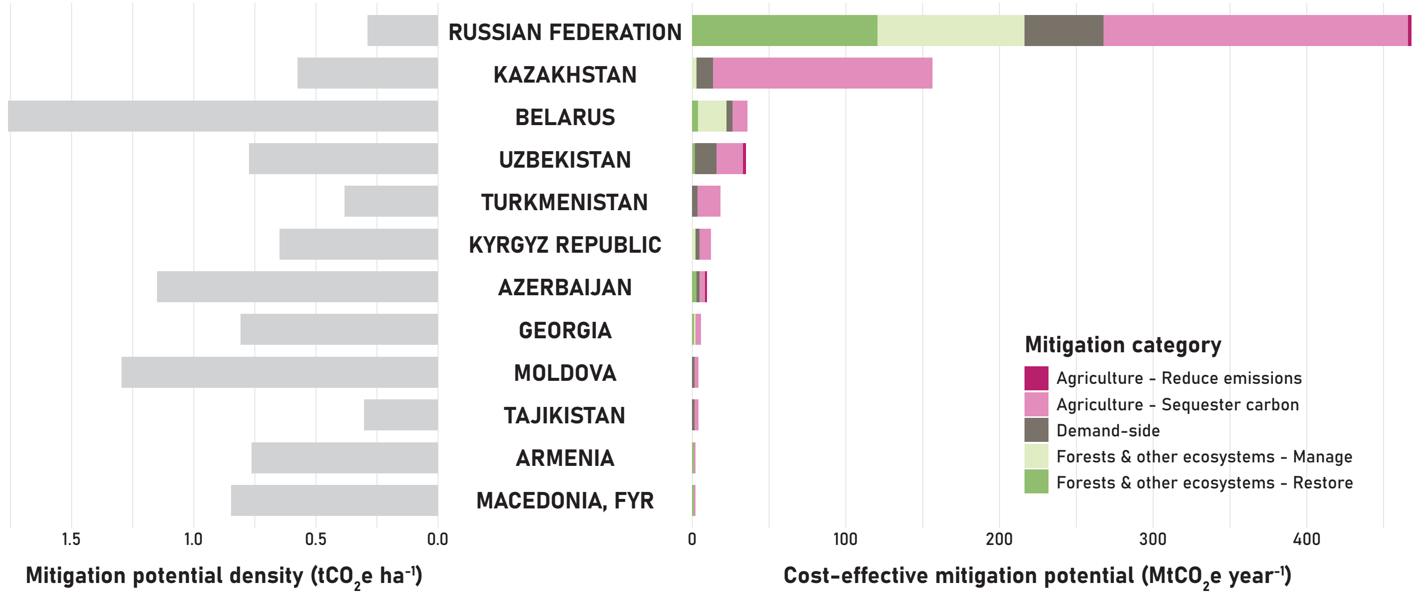


Figure 28. Eastern Europe and West-Central Asia land-based cost-effective mitigation potentials by mitigation category (colored bars) and mitigation density of cost-effective potentials (gray bars) by country.
Source: Roe et al. (2021).

Using a mark-to-market method, the World Bank evaluated the monetized cumulative value of the carbon sequestration potential of Kazakhstan to be approximately US$ 16.5 to US$ 33 billion by 2050. The annual value is US$ 0.63 to US$ 1.27 billion. This assumes a price of US$ 5-20 /tCO2 with the discount value equivalent to the annual price increase in VCMs. The value of emission reductions will likely increase in the future.[184]

Box 4.9. Taking Insights from the Fairtrade Minimum Pricing Model

Fairtrade carbon credits organized by Fairtrade International are one example of a robust pricing mechanism for carbon credits traded in VCMs derived from the Fair Minimum Pricing Premium Model. The model accounts for the broader origins of carbon credit projects and seeks to calculate a 'fairer' price that ensures the sustainability of the project and allocates a Fairtrade Premium dedicated toward promoting co-benefits such as climate adaptation or welfare for local beneficiaries. A Fairtrade premium is an additional revenue intended to be reinvested into community projects or scaling of the farmers' activities.

The Fairtrade minimum pricing model first relies on calculating a minimum price that covers the mean cost of projects in each category and adds a premium distributed directly toward funding co-benefits such as climate adaptation of the local communities. Currently, the Fairtrade applies this pricing strategy to its carbon credits sourced from activities in energy efficiency, renewable energy, and forest management. Furthermore, Fairtrade Climate Standard, a criteria the organization uses in overseeing the transactional parties of its carbon credits, emphasizes that organizations generating 1000 tCO2e per year wishing to purchase credits must calculate their carbon footprint, show 'meaningful action to reduce' it, and 'compensate for what cannot be reduced'.[182]

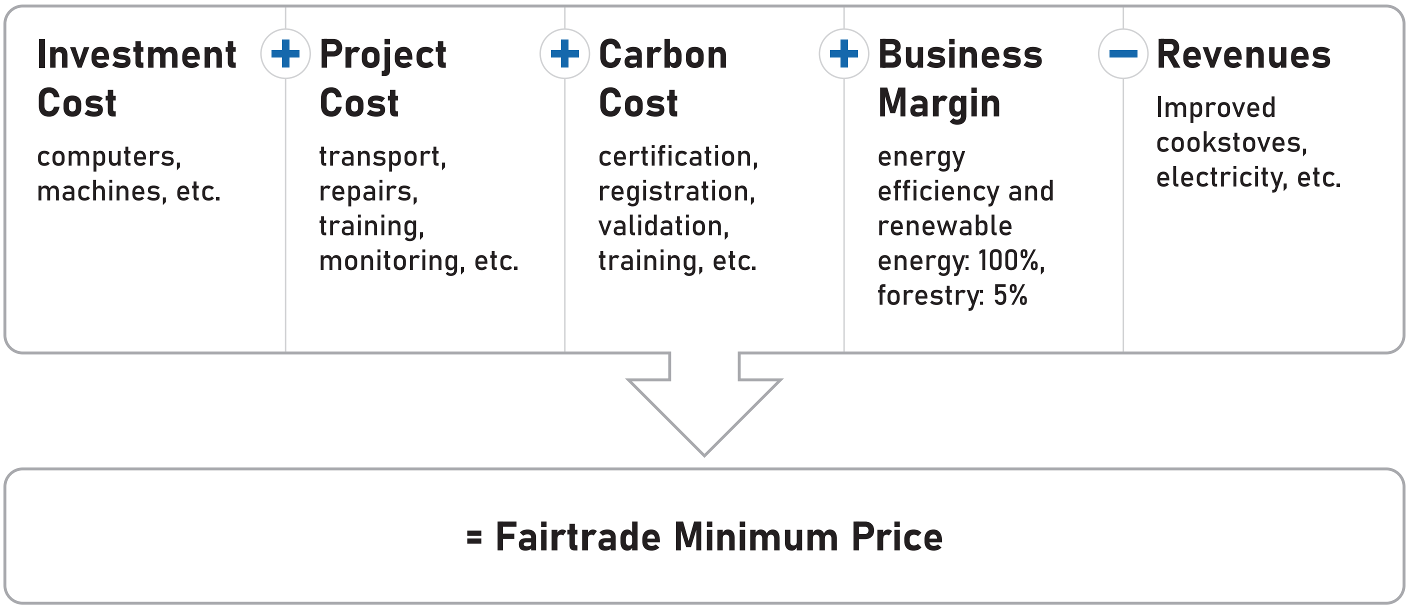


Figure 29. Calculating the Fairtrade minimum price for carbon credits.
Source: FairTrade.

Such a model could inspire how Kazakhstan could price the carbon credits since it could provide income stability for local farmers and greater bargaining power helping create more equitable trade relations. Adding a premium would ensure that co-benefits such as LDN, ecosystem restoration, and climate resilience for local farmers continue by allowing for a revenue to be earned which can be reinvested into these areas. However, this model also presents its challenges. Firstly, as with any minimum pricing model, there is a risk of market distortion, especially if the business margin is set too high, which could encourage an oversupply of credits from farmers and, without proper monitoring and regulatory supervision, may even encourage inefficient carbon farming practices or carbon leakages. Secondly, the minimum pricing model risks making Kazakhstan's carbon credits supply less competitive than other, cheaper credits. Finally, setting a minimum price can hinder farmers from benefitting if the price of carbon credits is greater than the minimum, although this is not yet a concern given the significantly low prices at which carbon credits are currently being traded.

4.4 Demand Side Considerations of Carbon Credits

The ability of Kazakhstan to trade carbon credits sourced from carbon farming projects domestically and with other countries will depend on the national and international climate mitigation and adaptation policies as well as behavioral change of consumers. These factors will determine the dynamics of demand and supply. Of a major concern for Kazakhstan is the EU CBAM and other similar tariffs being imposed on products imported from the country to the jurisdictions subject to such mechanisms. Kazakhstan's LEDS 2060 Strategy recognizes this challenge since carbon-intensive projects risk becoming locked out assets by importers given that the country is a major exporter of carbon-intensive products. On the other hand, policies such as CBAM could increase domestic and international demand for offsets if they allow offsets to count toward emissions reductions. Given the recency of implementing this policy, the impact of CBAM on VCM demand or offsetting demand, in general, is yet to be seen.

Box 4.10. EU Carbon Border Adjustment Mechanism (CBAM)

The EU CBAM earmarks a serious shift toward climate policies that reach beyond national borders and influence global trading ties. Importers trading with countries of the bloc will be obliged to pay a carbon fee on products embedded with carbon emissions in their production process. The CBAM will begin operating in October 2023 regulating fertilizers, cement, iron and steel, cement, aluminum, fertilizers and electricity for CO_2 emissions as well as other GHG emissions. The US has shown significant interest in implementing its own border adjustment mechanisms for imports on emissions intensive products.

The CBAM has been designed with two objectives in mind. Firstly, it is set to ensure that imported goods or services are priced at least in line with the pricing of domestic products with embedded emissions since the EU's products are already subject to various carbon taxes and compliances, which reduce the price competitiveness of these products. In doing so, it also aims to reduce potential 'carbon leakages' as the EU entities may seek to shift their pollutive productions in countries where regulations are less stringent.

Secondly, the CBAM relies on what is known as the Brussels Effect, whereby the policy is designed to encourage the acceleration of emissions reductions from organizations from other countries to avoid being priced out by CBAM. The roll-out of CBAM will coincide with the eventual phasing out of free allocation of carbon allowances under the EU ETS (see Chapter 5.1), expected to begin in 2026.

According to estimates of the World Bank, 'the European Union's Carbon Border Adjustment Mechanism (CBAM) could cost Kazakhstan US$ 250 million in export receipts annually from iron and steel, and up to US$ 1.5 billion if the scope of CBAM is expanded to include crude oil'.[177]

China represents another key stakeholder for Kazakhstan. China shows an enormous demand potential for carbon credits; however, it poses as a competitor in the supply of carbon credits on global voluntary markets. The country has already become the largest supplier of carbon credits to global VCMs. Furthermore, the CCER voluntary program, expected to relaunch in late 2023, is set to create profound changes in the global trading of carbon credits.[4] The program launched a domestic registry that competes for Chinese demand for carbon credits with global VCMs. The relaunch of the CCER could shift Chinese corporations' demand away from VCMs, thereby having negative implications for Kazakhstan's prospects. Furthermore, CCER regulators seek to certify several export credits, known as corresponding adjustment credits, which could be sold on VCMs or over-the-counter credits.

Staying under the 2C or even more so 1.5C climate will be extremely difficult without bolder efforts from non-state actors, including multinational corporations and private businesses. Especially given the slow pace of diplomatic efforts in attaining climate finance for developing countries, private sectors could become an essential source of investments and funding for climate mitigation and adaptation progress. Reducing own emissions is one, but not the only, way corporations can contribute. By investing in projects aimed at reducing and removing CO_2 directly through purchasing carbon credits, firms can increase their contribution to combating climate change and reducing the financial gap that limits countries in developing new means of climate adaptation and mitigation in the short run.

Box 4.11. Defining Scope 1,2,3 Emissions

Scope 1,2 and 3 emissions standards, developed by the Greenhouse Gas Protocol, spearheaded by the partnership of the World Resources Institute, and the World Business Council for Sustainable Development, have been designed to improve standardization in the accounting of emissions by organizations in various industries and encourage reductions even in indirect emissions. Most companies report their emissions based on the definitions of Scope 1,2,3, out of either mandatory obligations, as will be the case with the EU's Corporate Sustainability Reporting Directive coming into effect in 2025, or out of CSR.[185]

Scope 1 includes direct emissions caused by the sources that are owned or controlled by an organization. For example, emissions caused by data centers of a technology company belong to Scope 1 for the company. **Scope 2** includes indirect emissions created by the production of energy purchased by an organization. For example, emissions caused by the fossil fuels burned in providing electricity to bank branches belong to Scope 2 for the bank. **Scope 3** includes indirect emissions caused in the organization's value chain including emissions produced by consumption or by the supply chain in the production. For example, emissions caused by driving of vehicles by consumers belong to Scope 3 for a car manufacturer. Delivering on Scope 3 emissions is the most challenging since they are outside the organizations' direct control.

The need for net emissions reductions from private organizations, businesses, and even households will undoubtedly expand the sources of demand for carbon credits in the coming years. For industries with hard-to-abate Scope 1 emissions (see Box 4.11), such as construction, chemicals, and mining carbon emissions will remain an inevitable part of their existing production process without significant innovation in their production processes in the short run. Although some progress has been made in increasing productive efficiency, electrification, and low carbon-intensity products, such industries will likely continue to use carbon credits as a means of offsetting their emissions intensive production processes.

Several other sectors with significant Scope 2 and 3 emissions can present potential demand for carbon credits worldwide. Sectors including technological firms and digital platform ecosystems, entertainment, retail, and manufacturing all have significant emissions in consumption and are more susceptible to consumer sentiments. Such 'customer-facing' industries are motivated in their participation in VCMs to meet self-set net zero targets and CSR responsibilities to appeal to consumer demand (see Box 4.11). Furthermore, service-led industries such as banking and investment do not have high Scope 1 and relatively less Scope 2 emissions. However, they may play a significant role in facilitating emissions by, for example, providing loans, investments, technical assistance, or management services such that they may have significant scope 3 emissions. Therefore, the mounting of consumer or policy pressure on companies to take responsibility also for their Scope 3 emissions will likely increase the demand for carbon offsets.

Box 4.12. Microsoft: A Pledge to Become Carbon Negative by 2030

In 2020, Microsoft announced its commitment to become carbon negative by 2030 for Scope 1,2, and 3 emissions. By 2050, the company also plans to remove all historical Scope 1 and 2 emissions since its founding in 1975.[186]

Microsoft has become exemplary for corporate initiatives toward emissions reduction and sustainability. In 2012, the company achieved carbon neutrality through measures including the purchasing of carbon credits, setting up an internal carbon tax chargeable to internal business groups, and increasing the share of renewables in its energy consumption in various locations. Importantly, Microsoft became carbon neutral largely through the purchasing carbon avoidance credits which focus on averting environmentally harmful activities such as deforestation or paying for the reparation of oil pipelines to avoid leakages. Although carbon avoidance helps limit the addition of emissions into the atmosphere, it does not reduce or remove existing emission levels.

Hence, Microsoft's ambitions to carbon negative earmarks a new standard for private organizations to strive toward which is better in line with the pathways toward remaining within the 2C Paris Agreement Target. The company has set ambition to construct a portfolio of negative emissions technologies from NBS including from reforestation, biofuel and BECCS solutions, and soil carbon sequestration; as well as engineered solutions such as Direct Air Capture (DAC). The company aims to invest US$ 1 billion by 2024 into the creation and deployment of various carbon removal technologies as part of its Climate Innovation Fund and engage with various institutions in the knowledge production and long-term procurement of technologies helping Microsoft to reach its carbon negative target. In 2021, Microsoft contracted 1.3 million GHG emission offsets of which 193,000 tons belong to soil carbon sequestration projects, 2,000 tons from bioenergy, 2,000 tons from biochar projects, and 1,000 tons from DAC.[186]

The market of carbon removal projects still lacks the refinement and maturity needed to meet demand for high-quality removal credits at such a large scale. For example, Microsoft received proposals from 189 projects on carbon removals, however, only 55 megatons of carbon were immediately available and of those, only 2 megatons met the company's criteria for high-quality removals.[187] The example of Microsoft can provide aspiration for how Kazakhstan can benefit from the growing demand for carbon removals, if the country implements and accelerates carbon farming that assures quality and integrity for buyers.

5. From Seed to Sow: Scaling the Value Chain of Carbon Farming in Kazakhstan

5.1 Current Developments of Climate Policy in Kazakhstan

Kazakhstan signed the Paris Agreement on August 2, 2016, and ratified it on December 6, 2016. Kazakhstan's first NDC (updated in 2023) provides for a reduction of GHG emissions, by the end of 2030, by 15% below the 1990 level unconditionally and by 25% below the 1990 level subject to international assistance. The Ministry of Ecology and Natural Resources of the Republic of Kazakhstan is the authority in charge of implementation of international agreements on climate change, including regulation of GHG emissions and removals and achievement of the country's NDC. Other state organs are responsible for taking action within their competence to implement the NDC.

At the Climate Ambition Summit on December 12, 2020, President of Kazakhstan Kassym-Jomart Tokayev announced the country's intention to achieve carbon neutrality by 2060. To that end, the Carbon Neutrality Strategy has been adopted which envisions a more than three-fold reduction in the share of fossil energy resources in the fuel and energy mix down to 29% with the share of renewable energy increasing from 3% to 70% by 2060.[30] Furthermore, the country's updated Environmental Code (2021) establishes the 'polluter pays and remedies' principle and includes a dedicated section on adaptation which aims to mitigate adverse impacts of climate change on human health, ecosystems, society, and the economy while capturing benefits from opportunities offered by climate change. Agriculture, forestry, water, and civil protection are identified as four priority sectors for adaptation measures.

An ETS has been in operation in Kazakhstan since 2013. It covers 225 major installations with annual emissions in excess of 20,000 tCO2 in the electricity generation, oil and gas, mining, metallurgy, chemicals and manufacturing sector (the latter encompassing a limited range of construction materials—cement, lime, plaster, and bricks). Smaller installations as well as agriculture and transport are excluded due to complexity of administration. Kazakhstan's ETS covers carbon dioxide emissions only.

The National Plan for GHG Emission Allowance Allocation provides for emissions benchmarking and therefore follows the 'bottom-up' approach to allowance allocation. The annual reduction factor of 1.5% is applied, so that the allowance for each subsequent year must be at least 1.5% below that of the previous year. Kazakhstan's emission allowances are currently trading at prices which are a small fraction of those in foreign allowance markets. Although Kazakhstan is currently working to align its ETS with the EU model, the country's market has yet to deliver substantive emission reductions.

Growing emissions in sectors outside the ETS are pushing the government to consider options for introducing carbon pricing for such unregulated sectors. Kazakhstan's NDC states that a decision in this regard will be based on 'best scientific knowledge, comprehensive modeling, in-depth scenario analysis, and cost-benefit analysis.' To facilitate Kazakhstan's low carbon and green transition, the Environmental Code provides for the use of best available technologies to reduce adverse anthropogenic impacts on the environment and improve efficient use of resources. Facilities with a significant adverse impact on the environment require an environmental permit which is issued subject to the implementation of best available technologies.

The following initiatives are relevant to reduction of GHG emissions in Kazakhstan:

- Fuel and Energy Complex Development Concept in the Republic of Kazakhstan for 2023–2029 (2023).
- The National Project 'Sustainable Economic Growth Aimed for Well-being of Kazakh Citizens' (2021).
- The National Project 'Green Kazakhstan' (2021).

Key indicators include:

- The share of electricity from renewable energy sources: 12.5% of total production by 2029.
- Country-wide gasification rate: 63.4% by 2029.
- Decrease in energy intensity in the energy sector by 5% below the 2021 level by 2029.

Deployment of renewable energy is the primary focus for the development of Kazakhstan's energy sector. The country currently has 130 renewable energy facilities with a total installed capacity of 2,400 MW. With the government actively attracting investments into the renewable energies sector, the share of renewables in electricity production is expected to increase to 15% by 2030. Fifteen facilities with a total capacity of 276 MW were planned to be commissioned in 2023. An intergovernmental agreement with France (Total) for the construction of a 1-GW wind power project has been signed.

Fifteen renewable energy projects with a total capacity of 440 MW, including 400 MW of wind energy and 40 MW of solar energy, were selected through auctions in 2022. The lowest-in-history price for wind energy has been 12.49 KZT, which is less than US$ 0.3 per kWh and close to the global record. Renewable energy producers may feed electricity generated from renewables into the general grid at special rates. They are also exempt from paying electricity transmission fees and are prioritized for access to the grid.

Another priority area is gasification. The country's overall gasification rate is 54.3% and must increase to 63.4% by 2029. The government is working on enhancing gasification of the northern and eastern regions of the country. It is expected that the Central Asia-Center gas pipeline system, which has been used starting from October 7 to transit Russian natural gas through Kazakhstan to Uzbekistan, may contribute to reaching this target. Kazakhstan has recently been considering the construction of a nuclear power plant (potentially in the Ulken Zhambyl district of the Almaty region). President Tokayev proposed on September 1, 2023 to hold a referendum concerning this question. The exact timing for the referendum is yet to be set up, though. Companies from China, Russia, South Korea, and France are being considered as potential technology providers.

Importantly, Kazakhstan recognizes the potential of carbon farming toward accelerating the country's efforts to decarbonize in its LEDS 2060 under section 3.3.1.3. Agriculture and Forestry.[30] It specifies the country's ambition to scale up climate-optimized agricultural practices, especially through the development of carbon farming, as well as introduce principles of precision farming and exploration of climate-resistant crops and organic agricultural practices. The section discusses the potential for evolving land-use in agriculture such that the sector may act as a net sink of CO_2 for emissions generated within the sector as well as in other sectors by 2060. The strategy also highlights the opportunities from increasing sustainable agricultural practices including the expansion of irrigation systems, increasing crop rotation and crop diversification which could improve soil health and recovery.

Agroforestry and organic agricultural practices are recognized as part of a wider aim to increase regenerative agricultural practices to ensure future food security as well as re-integrate biodiversity into agriculture.

In addition, LEDS 2060 elaborates on the advantages of integrating agricultural waste into the decarbonization plan for creation of fuel and other resources.

For example, agricultural waste, through the use of decomposition technologies or anaerobic digestion plants, can be used to produce biogas for heating and power generation, while the soil residues from anaerobic digestion may be used as natural fertilizers that are less potent and pollutive than the current chemical fertilizers.

Kazakhstan's LEDS Strategy also points out the country's useful positioning to attract climate financing through the ETS, green finance schemes, and international public and private investments. Furthermore, the strategy supports the notion of developing a national carbon fund which could accumulate investments and financial resources from various channels such as the sale of carbon credits and carbon allowances or the introduction of a carbon tax, for investing into projects which aim to reduce emissions or increase GHG absorption. The country has already increased its diplomatic efforts to build ties with other nations on the basis of climate-change mitigation. For example, in October 2023, Kazakhstan signed a memorandum of cooperation to launch the UNFCCC Joint Crediting Mechanism in the country, becoming the 28th partner to do so. Furthermore, the memorandum was signed in cooperation with the Government of Japan and established Japan's support toward NDC targets of both countries by implementing emissions reduction projects in Kazakhstan as per the conditions of the Joint Crediting Mechanism.[188]

Box 5.1. Investing in Saxaul Plantations in Kazakhstan

The Government of Kazakhstan has implemented environmental initiatives jointly with international institutions and funding organizations. For example, in 2007, the Ministry of Agriculture set out to pilot replantation of saxaul trees in the Kyzylorda Region as part of a joint project with the World Bank Forest Protection and Afforestation Project. Between 2008 and 2014, approximately 56.5 thousand hectares of plantations were established with the survival rate ranging from 5 to 40%. During 2009 and 2019, various international grants and funding aided the development of forest plantations around the Aral Sea's north-eastern regions. Under the grants of international funds such as the International Fund for Saving the Aral Sea, Japan's environmental organizations (Environmental Restoration and Conversion Agency, National Land Afforestation Promotion Organization, AEON Environmental Foundation, Green Fund, Risona Fund) and Japan's Embassy in Kazakhstan, protective forest plantations were created in Aral Sea Region's northeast.[189]

5.2 Engaging Participants into Carbon Farming

Typically, and in Kazakhstan, carbon farming will involve a bottom-up production process, whereby carbon farmers will undertake sequestration activities. To facilitate this process, a top-down initiative from jurisdictional institutions to establish a proper legal and institutional framework alongside financial and other kinds of governmental support will be required. Inter alia, engagement between Kazakhstan's policymakers and farmers and their communities is needed to foster trust-building and knowledge transfers between the various participants. Communication channels between farmers, local authorities, and other organizations will uphold and improve throughout the lifespan of any carbon farming initiative. Crucial for this engagement is to understand farmers' incentives, circumstances, and concerns regarding carbon farming.

Almost 45% of Kazakhstan's population reside in rural regions. Poverty rates in rural regions can be twice as high compared to urban settlements of the country and there remain significant disparities in the living standards and per capita consumption rates between the rural and urban areas. Changing climate and the transition toward decarbonization may disproportionately impact rural regions where coal is still used as a primary heating source in two thirds of all rural households.[177] Ultimately, carbon farming must provide a sustained increase in income for farmers to ensure their retention in developing the value chain. The sale of carbon credits could provide farmers with additional financial benefits from changing to carbon sequestration and restorative activities. The increased income for farming communities should contribute toward improved economic welfare and social development of these regions facilitated also by local and regional authorities.

However, engaging farmers and rural communities must be approached carefully and with awareness of their hesitations and concerns. Addressing skepticism from farmers in joining carbon farming projects is, however, an issue not unique to Kazakhstan. As an example, the EU's European Regional Development Fund published a white paper analyzing the main factors that limit EU farmers from starting carbon farming. Its survey results demonstrate that insufficient knowledge on carbon farming and restrictive or counter-productive policies were two of the key reasons limiting EU farmers from carbon farming.[190]

Such insights are also applicable to Kazakhstan. Firstly, insufficient knowledge is highly likely to concern farmers in Kazakhstan. To address this, authorities and researchers must explore schemes supporting carbon sequestration investigations specific to the heterogenous conditions of the country's regions. Through information and innovation gathered from testing centres and pilot projects, a practical understanding of the impact of carbon farming on individual farms and guidance on measuring short-term soil improvements could be developed. Tailor-made advice is essential for farmers; communication channels with researchers or local managerial institutions may provide immediate support to farmers, particularly in the early stages of the regional scaling for carbon farming.

In the context of Kazakhstan, restrictive land-use policies and underdevelopment of agricultural technologies may also hinder engagement for carbon farming. Kazakhstan granted land under life-long possession to rural households in 1991 and successively to commercial farmers in 2003 which allows land use for agricultural purposes only. However, the legislature for agricultural land use is still lacking complete implementation.[191] Almost 99% of agricultural land technically remains under long-term lease contracts or state control, and the regulatory environment for land use in Kazakhstan remains weak, negatively impacting the second challenge, farmers' trust. The unpredictability and bureaucracy of local authorities have undermined trust in regulatory institutions.

Restrictions in land use change, new farming techniques, land ownership, and agricultural regulations must hence be coherent with the desired outcomes for carbon farming to ensure that local farmers are not penalized for their new practices. Thus, Kazakhstan's policymakers could benefit from prioritizing a systems approach for carbon farming that eliminates contradictions within various environmental targets and accounts for the economic compensations and feasibility for farmers to retain efforts into carbon sequestration over the long term.

Box 5.2. Synergistic Actions to Facilitate Knowledge of Carbon Farming

Carbon farming is still a relatively young concept and implementing such a scheme on a large scale requires structural systemic changes in the mindset and methods that govern processes including soil management, ecosystem management, incentivization, and tailored guidance. Farmers cannot initiate these shifts particularly if they are not equipped with the technical understanding of the implementation of carbon farming practices or lack the incentives to engage. Policymakers can facilitate engagement with local communities in terms of governance, compensation, and socio-economic co-benefits, however, they cannot drive the technical knowledge production required by farmers to implement carbon farming. This is the role of scientific research.[190] Yet, there is a gap between the pace at which relevant research is being conducted versus the slower pace at which the information and training is reaching farmers. Small-scale farmers require a tailored understanding of implementing carbon farming and effective training in the monitoring, managing and registering their soil carbon stock and natural resources. Various effects of carbon farming are currently being studied separately and not as a combination of measures with synergistic outcomes. Therefore, it is paramount that regulators and governments facilitate engagement between researchers and farmers to support the production and dissemination of knowledge on carbon farming that is tailored to the circumstances of local farmers and their communities.

5.3 Governance Structures and Fiscal Instruments for Carbon Farming

To scale up carbon farming at a national level, the Government of Kazakhstan may wish to consider two key aspects. Firstly, to identify and apply the most cost-effective measures and allocate fiscal support measures (alongside non-governmental measures of financialization as discussed in Section 5.5), especially in the early stages. Secondly, establishing sound governance structures is imperative for the implementation of carbon sequestration and farming projects, monitoring and pooling of small-scale project outcomes, and to ensure delivery of the relevant fiscal support and compensation to farmers and other stakeholders. The scalability and resilience of Kazakhstan's carbon farming industry will depend on its governance and fiscal interventions, trust between the producers, consumers, and governing institutions, and appropriate incentivization of long-term participation in carbon sequestration activities for farmers. Kazakhstan would benefit from introducing the following principles in its governance system:

1. **People-centric approach ensuring that** carbon farming is feasible for local farmers and yields long-term improvements in economic welfare and development for the communities.
2. **Systems-based approach,** thereby considering in a holistic fashion direct and indirect impacts of decisions and implementation of cost-effective strategies that aim to achieve the highest synergistic impact. Importantly, governing institutions must ensure that their decisions do not create negative side effects, e.g., aggravating water stress through carbon farming. This also includes a strategic view of cross-sectoral linkages between agriculture and land management and, for example, the water-energy-food-ecosystem nexus.
3. **Step-by-step implementation** of carbon farming guided by scientific knowledge with pilots and feasibility studies providing information regarding affordability, political capacities, and overall national context.
4. **Risk-sharing mechanisms** to cover economic uncertainties such as low pricing, low demand, and inflationary bubbles; environmental uncertainties such as natural disasters, infrequent rainfall, or drought; political uncertainties such as changes in international relations; and social uncertainties such as changes in the needs of local and rural communities.
5. **Learning from international experiences** and continuous cooperation with international and domestic development partners.
6. **Prioritising legally binding obligations** of Kazakhstan i.e., the required measures for climate change as per the Paris Agreement whilst also harmonizing voluntary ambitions.
7. **Policy consistency and coherence, coordination, and integration.**

The consolidated budget of the Republic of Kazakhstan consists of the following separate elements: the republic budget, budgets of regions (oblasts), the capital City of Astana, the City of Almaty, and the budgets of rayons and of capital cities of oblasts. For simplicity, hereafter they are collectively referred to as public budgets. The long-term social and economic benefits (see Chapter 6 for more information) of carbon farming practices for Kazakhstan provides ground for investment of state support measures into scaling carbon farming using different instruments such as fiscal incentives (e.g., through applying privileged tax rates or tax credits) and budget guarantees to loans to direct (co-) funding from the public budget.

Increased agriculture productivity and a diversified rural economy will expand the tax base, which is another argument in favor of public expenditure to create and scale up the carbon farming program. Part of these benefits will go to the jurisdiction as well to the producers of carbon credits, such as farmers, in the form of payments for their output. However, a part of this revenue could be directed to the national and regional budgets. Therefore, upfront public spendings to launch and scale up the carbon farming program may have a net positive long-term effect on the budget.

Identifying appropriate fiscal policies and cost-effective state support measures is only possible once the suitable methods for carbon farming have been selected. However, insights can be taken from previous fiscal policies and state support instruments implemented in Kazakhstan. It helps to preliminarily identify state support measures which will be required for the foreseeable activities required for an effective implementation of carbon farming programs. For example, relevant institutions and regulatory framework for the management of carbon farming programs could be established using public budget funds from the republic or oblast level budgets. Similarly, public budgets could also finance seed investments for early projects that prioritize community co-benefits which could yield immediate benefits for local communities such as planting saxaul trees in semi-desert areas near Aral Sea (Box 5.2) or restoring Tugay forests in floodplains of Ili and Syr-Darya rivers. Regional and local level public budgets could (co-)finance measures such as creating or expanding green zones in and around human settlements and measures to prevent or substantially diminish harm from natural disasters and could be delegated to private sector partners such as leasers of respective land (PPP schemas).

Other fiscal instruments could encourage additional SLM practices at farm level. These practices may be funded by providing an additional income source for farmers for activities including planting protective forest belts around fields on state-owned leased agricultural land to sequester carbon and increase land productivity. Furthermore, fiscal support could be directed toward managing risks including reducing carbon leakage due to wind and water erosion or ensuring permanence of sequestration against climate disaster risks. Lastly, fiscal policies could be used to incentivize domestic purchases of carbon credits, for example, by implementing a border adjustment tax (see Section 4.4) and tariffs on imports with embedded carbon emissions or integrating carbon credits into the existing ETS scheme (see Section 4.1).

Kazakhstan already directs significant fiscal support toward its agricultural sector. For example, Kazakhstan implemented per hectare subsidies for crops such as sugar beet, rice, cotton, vegetables, melons, grains, oilseeds, and potatoes. Transfers have also been conducted to cover the cost of intermediate input such as irrigation infrastructures or capital costs. Concessional credits have been applied for costs of intermediate inputs of sowing as well as concessional investment credits and micro-credits for construction or leasing of greenhouses. Lastly, transfers have also been made to support knowledge creation such as applied research on the agro - industrial complex constructions or provision of methodological advice on preservation of water systems. In 2021, US$ 22 million was directed toward various agricultural subsidy programs including 24,189 agricultural investment projects which led to the creation of 20,183 jobs.[192]

However, recent analyses (e.g. by the OECD[82, 83]) suggested that Kazakhstan's agricultural subsidies had not always been cost-effective or sufficient. The former concerned, e.g., the per hectare subsidies. On the other hand, there remains capacity for increasing cost-effective subsidies, e.g., in the construction of rural roads and local storage and processing facilities (foremost, for fruits and vegetables), as well as in developing collector-drainage systems (increasing the productivity of irrigated land) and rural water supply and sanitation systems.

In designing a set of state support instruments for carbon farming, it is recommended to consider and ex ante assess support instruments using established methodologies (see Box 5.3) to address the key aspects. Firstly, the fiscal instruments should support synergistic actions between carbon farming, commercial agriculture, land-use, and water. For example, conditional state support could be made available for farmers at risk of wind or water erosion to cultivate forest belts and appropriate shelterbelt hedgerows or shrubs around farmland which contributed toward carbon sequestration and reduces soil degradation and dryness from heat. Secondly, the fiscal instruments must take into consideration the indirect gains and losses.

Thirdly, immediate compensations could be prioritized for farmers to incentivize early engagement, e.g., in the form of advance payments for ex-ante production of carbon credits or providing non-monetary benefits including free training and maintenance support on implementing carbon farming.

Overtime, as carbon farming expands and becomes profitable, Kazakhstan can set up measures of revenue recycling, whereby the public revenue generated from carbon farming can be re-invested into supporting expansion and scaling of carbon farming, and importantly, supporting the farming communities in their development and welfare. Policymakers can consider establishing both state-owned revolving fund and private fund(s); for example, issuing private bonds and using the equity & proceeds from bonds for issuing loans to farmers; and target different new means of generating carbon credits that could be sold on either compliance markets, or on (private) voluntary markets.

Furthermore, although Kazakhstan's agricultural sector is a major industry, it is relatively under-financed and relies on depreciated technologies. 94% of tractors in use have been so for over 10 years and the rate of machinery renewal has been significantly lower than required. While the country has subsidized purchasing of machinery from Belarus, Russia, and Ukraine in recent years, which has supported machinery replacements, agricultural equipment imports from other countries are taxed at 40% which reduces its accessibility and affordability for farmers.[193]

Box 5.3. OECD-EU Methodology for Assessing Support Instruments

The OECD-EU Methodology for Assessing Support Instruments, originally designed for interventions related to government subsidies and fiscal support provides a comprehensive list of the key aspects of consideration when setting up compensation and subsidization mechanisms for environmental projects and activities. The aspects for evaluation are:

1. Effectiveness in relation to established (and/or desirable) policy objectives. What is the potential of the instrument to help achieve established and/or desirable policy objectives? How will the design of the instrument affect its effectiveness? What is the potential for the instrument to cause a switch to other environmentally or economically damaging behaviour?
2. Revenue generation potential. How much revenue will be raised? How could this revenue be used for policy objectives or to replace more distorting taxes?
3. Cost-efficiency. How economically efficient is the instrument in achieving given policy objectives?
4. Ease of administration. How easy would it be to implement, ensure compliance and monitor the instrument?
5. Consistency with institutional framework. Is the instrument consistent with the polluter pays & beneficiary pays principles, the precautionary principle or other policy objectives? Does it conform to international agreements to which the state is a signatory or with which it wishes to harmonize?
6. Dynamic efficiency. What is the impact of the instrument on long-term economic efficiency? Are there incentives for the long-term development of new technologies and practices?

7. Impact on income distribution/equity. How would the instrument affect income distribution? Would it benefit or harm any particular social group? Could revenues be used to mitigate these effects?
8. Impact on competition. How will the instrument distort competition within agriculture, forestry, other sectors and internationally?
9. Political and social acceptability. What are the possible barriers to political and social acceptance? What is the previous experience with similar instruments? What actions can be taken to improve acceptability? How transparent is the implementation and operation of the instrument?

Setting up an appropriate governance and institutional framework is vital to delivering a sustainable and resilient supply chain for carbon credits through carbon farming. In building the relevant governance structures and institutions for the carbon farming value chain, Kazakhstan must keep the needs of the carbon farmers at the nucleus of their plan. To maintain consistency and sustainability, each of the institutions must be capable of guiding carbon farmers and maintaining transparency and integrity in compensating farmers. Furthermore, it is paramount that the institution set-up takes a systems-based approach to management and supervision. A systems-based approach involves holistic considerations of the environmental impact of carbon farming and ensuring that communities see positive economic and social outcomes over time.

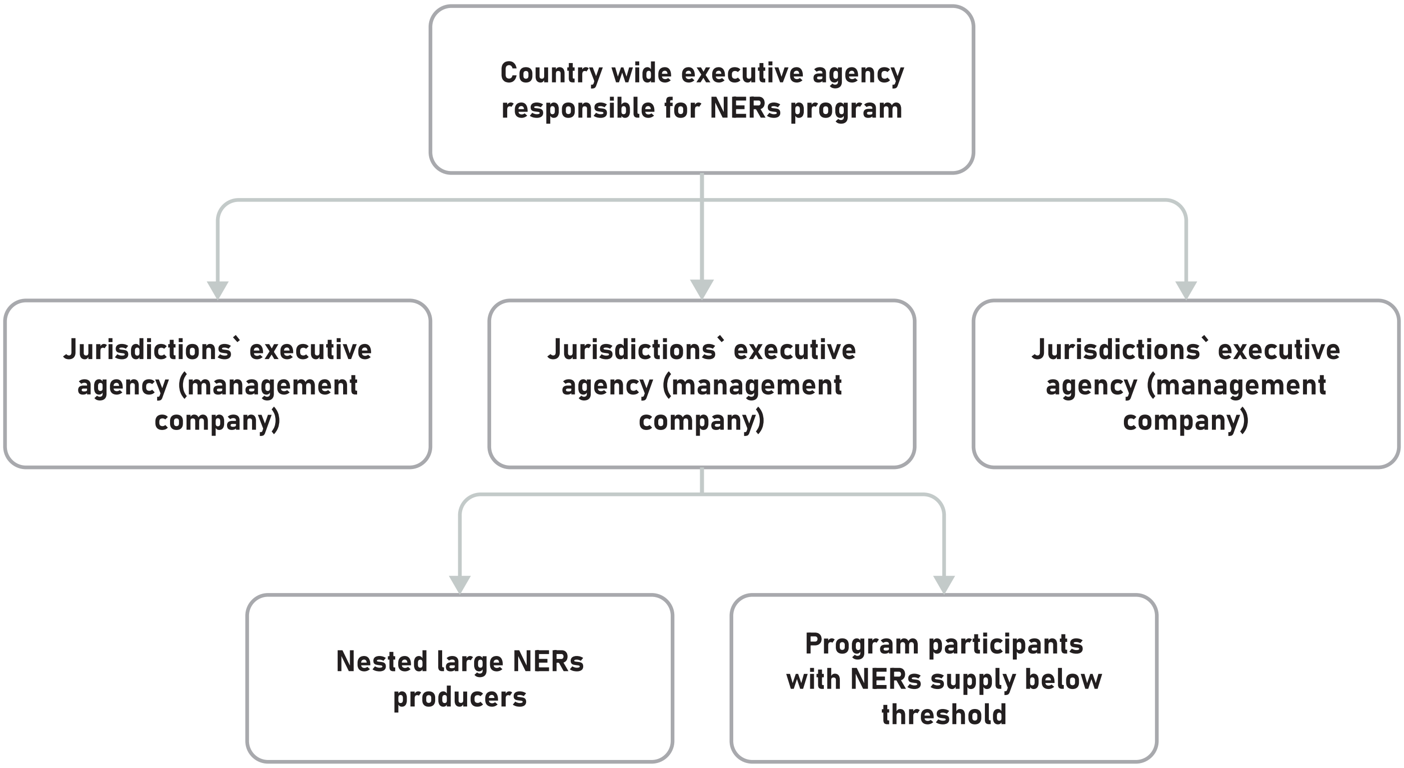


Figure 30. An illustrative diagram to show the possible governance structure for Kazakhstan.
Source: A contributor's elaboration.

First, a **national executive agency** that oversees all operations and coordinates the MRV practices must be set up to ensure the maintenance of MRV standards with the participating jurisdictional authorities. The national executive agency would also be involved in the national campaigning and planning for incentivization of carbon farming and play an intermediary role between the producers and buyers. It would also be responsible for managing carbon farming regulations as per the best available practices and conduct continuous interventions and updates to the policies with time. As the starting point, Kazakhstan may build procedures with those compliance markets which currently allow for international carbon credits as this will create a foundation to offer carbon credits in compliance markets and use them to offset Scope 1 and 2 emissions embedded in exports as discussed in Section 4.4. Furthermore, a clear definition of additionality must be determined at the national level.

Kazakhstan could either set up a new governance structure, such as an inter-ministerial committee on climate-related issues, or with a broader responsibility for water and food security while ensuring the sustainability of respective ecosystems.

Such a structure would also require establishing an Executive secretariat to deal with routine work and provide advice and clerical assistance to the committee. Alternatively, an effective existing institution may also be tasked to perform the relevant functions.

Next, **regional agencies at the oblast level** could be set up with alongside with local representation offices as subsidiaries of the national executing agency to provide accessible guidance and supervision of carbon farming projects. These territorial governance bodies would supervise the MRV practices, including maintaining regional registries and maintaining checks and supervision of the sequestration activities for the contracted duration. They could also manage buffers, mediate relations between national agencies and stakeholders and local stakeholders, and report back to the national executing agency. Both the **national and regional executing agencies** would also be involved in the execution of the country-wide policy to incentivize carbon farming, including playing an intermediary role between the producer and the buyer. Ultimately, the carbon credits generated at the local level could be checked and verified by the regional agencies, who report to the national executive agencies for final listing on registries.

There are two pathways in which carbon farmers can communicate with their localized executive institutions governing the system, depending on the size of the suppliers of carbon credits. For large-scale suppliers, e.g., vast farms or landowners, communication could be set up directly between them and the regional executive agencies to facilitate faster registration of their verified credits and manage efficient reporting and supervision. For small and medium-sized carbon farming projects that do not meet the output threshold of large-scale suppliers, regional authorities (Oblast Jurisdictional carbon farming) may explore pooling solutions to save on transactional and administrative costs. Then, farmed carbon is accounted for on the jurisdiction (oblast) level. Next, oblast trades carbon and distributed revenue among small stakeholders using simplified rules of individual farmers' contribution accounting while using state-of-the-art MRV procedures on a jurisdictional level.

In line with typical global practices, it is recommended first to identify the most promising categories of carbon farming and sequestration projects and test these under controlled environments through testing centers and later through pilot schemes in the regions of North Kazakhstan (steppe regions) and South Kazakhstan regions in Syr-Darya - North Aral, Chu-Talas and Ili -Balkhash- Alakol basins (see Chapters 2 and 3). Then, with support from developing partners, investors, and other stakeholders, governance structures tailored to the MRV practices of the selected carbon farming categories can be set up based on global verification standards and principles of governance such as the OECD Principles of Good Governance (of Regulators, and Corporate Governance).

5.4 Measurement, Reporting, and Verification for Quality Production of Carbon Credits

MRV practices are step-by-step procedures conducted to corroborate quality of carbon credits being traded on crediting mechanisms conducted by an independent private agency. With the rise of voluntary offsetting and decentralized carbon markets, verification has become an industry in its own respect. With several such agencies operating in global voluntary markets, a carbon credit can in principle be verified by multiple agencies which may even raise the value for the end buyer.

For certain types of nature-based offsetting and removal such as forest-based removals, MRV practices are already rather well-established. For example, the Forest Carbon Partnership Facility established a standard for measuring practices in forest-based emission abatement projects.[194] The Partnership for Market Implementation program administered by the World Bank also developed an open-source MRV system to support carbon capture and emissions reduction activities and financialization practices and track individual projects up to the national level; this system has been implemented in Jordan, Sri Lanka, and Palestine. Although methodologies for MRV in soil-based sequestration is relatively underdeveloped, some examples of good practices and guidance exist.

Box 5.4. Taking Insights on Verification Practice from Forest-Based Carbon Credits

Accounting and crediting standards play an essential role in facilitating the trade of high-quality forest carbon offsets. There are three verification standards applied to REDD+ projects which deliver methodologies for forest-based sequestration. The most popular are the ART-TREES standard, VERRA's JNR Framework, and the California's CTF standard.

The ART TREES standard provides guidance on the monitoring, report, and verification activities of GHG emissions reductions for countries and sub-national jurisdictions. ART implements the TREES verification standard projects within for its own electronic registry database of forest-based carbon credits which can be based across the world.[195] Entities can apply to open an account in the ART TREES registry. For projects conducting emissions offsetting activities, the ART board approves the issuance of TREES credits the emission offsetting activities of the project are verified and validated by ART.[196] The issued carbon credits are then listed on the registry for potential buyers and traders.

Similarly, VERRA implements JNR for REDD+ projects integrated into reducing emissions for government related targets such as NDCs and is integrated with its wider VCS program.[197] Lastly, the CTF standard was developed by the California Air Resources Board and provides a guidance and assessment criteria for REDD+ projects by various organizations and jurisdictions seeking to link their REDD+ programs with California's cap-and-trade program.[198]

All standards aim to establish criteria to produce high quality and high integrity emission reductions. ART-TREES and the JNR frameworks were designed to serve multiple markets, while the purpose of the CTF is to allow REDD+ credits into the California carbon market.

Although there are differences in crediting mechanisms, all three standards promote additionality and establish an ascending, conservative reference crediting baseline below historical emissions for avoided deforestation and forest restoration. ART-TREES and CTF standards specify formal procedures for computing high-quality emission reductions, while the JNR proposes a context-specific crediting mechanism.

The CTF requires a crediting baseline at least 10% below the reference level (10-years average historical emissions) that linearly declines to a jurisdictional-specific 2050 GHG emissions target for the forest sector. The ART-TREES reference period for the crediting is five years of the average historical emissions, to be updated every five years, creating an "endogenous" baseline while JNR establishes it at 4-6 years. More emission reductions in the first five years of program implementation by the jurisdiction result in a tighter baseline for the next five years. All standards crediting mechanisms are designed to prevent leakages, address residual risks and account for uncertainty.

Establishing a Baseline

The verification process of any project producing carbon credits begins first by the establishment of a baseline, i.e., the BAU scenario, that is, if the project had not been implemented. For Kazakhstan, establishing a baseline scenario is critical as unused lands in some regions have already shown signs of carbon sequestration,[199] which, although strengthens the argument for implementing carbon farming practices, also increases the risks in reporting for additionality of the intended projects since it may be difficult to demonstrate the impact of carbon farming from the carbon that is naturally sequestered. If degraded lands continue to sequestrate carbon such that implementation of a carbon farming project does not facilitate increased or enhanced sequestration, or is difficult to demonstrate, then the value-add of executing the project could be challenged.

To support the establishment of BAU as a baseline, project participants such as farmers, provide data based on historical records of their farming practices. Additionally, collecting data for baselines may involve physical sampling or soil carbon content measurements by quantification of the fine earth or coarse mineral, organic carbon concentration, and soil bulk density or fine earth mass to assess the existing level of carbon in the soil and potential rate of sequestration.[200] Where historical records are unavailable or require significant time investments, forward-looking baseline or a BAU approach may also be set which helps to identify the expected fluxes of carbon from the sequestration activities over the project's lifetime by adhering to certain assumptions on how conditions of the land are expected to evolve in the absence of any carbon farming activity. Certain verification standards such as the VCS recommend a renewal of the baseline every 10 years to ensure the project maintains and maximises its potential overtime.[201]

Data Collection during the Project

Once a baseline has been established and the project begins, carbon farmers or intermediary managers must collect data on the agricultural management practices and assess various biological and geological conditions of the areas to determine the impact of the implemented techniques. These measuring and monitoring activities thus serve as a basis for verification. By the end of each reporting period, the program participant has a new reference line for the stock of removed emissions.

The collected data from the sequestration practices are compiled into a report verified by an agency that evaluates and certifies the final carbon credit.

The monitoring report is foundational in assessing and eventually verifying a carbon credit. Firstly, reporting program must define the area under supervision, followed by an assessment of the change in the carbon content. For projects covering larger geographical areas, several different plots of land are usually considered to better account for the specifics of each sub-ecosystem carbon sequestration and storage. In Kazakhstan, a higher degree of homogeneity may be expected given the desertification of lands; thus, less granularity may be required for reporting and assessment. Implementation of innovative remote sensing methods and technologies may significantly cut monitoring costs and presumably improve the accuracy of estimations.

Climate Action Reserve SEP has been developed to support verification procedures of emission reductions through soil carbon sequestration on agricultural lands through the adoption of sustainable agricultural land management activities in the USA.[202] Table 2, taken from the recommendations provided by the Climate Action Reserve for soil sequestration in the US, lists qualitative and quantitative data collected for measuring the progress of land-use carbon farming projects including crucial geological, biological, and chemical information on the land and the management practices.

Agricultural Management Practice	Qualitative Data	Quantitative Data
Crop	· Crop type(s)	· Approximate date(s) planted (if applicable) · Approximate date(s) harvested / terminated (if applicable)

Soil amendments	· Manure (Y/N)
	· Other organic amendments (such as compost, biosolids etc.) (Y/N)
	· Synthetic N fertilizer (Y/N)
	· Crop residue removal approach:
	  · Minimal residue removal, e.g., grain only harvest
	  · Partial residue removal, e.g., baled straw
	  · Maximum residue harvest, e.g., silage
		· Manure application rate (if applicable)
		· Other organic amendment application rate (such as compost, biosolids etc., if applicable)
		· Synthetic N fertilizer application rate (if applicable)

Irrigation or other hydrological management	· Irrigation (Y/N) · Flooding (Y/N)	· Irrigation rate (if applicable)
Tillage	· Tillage (Y/N)	· Depth of tillage (if applicable)
Grazing	· Grazing (Y/N) · Animal type (if applicable)	· Animal stocking rate (if applicable)

Table 2. An example taken from US SEC on the qualitative and quantitative data required in monitoring carbon farming practices.
Source: Climate Action Reserve (2021).

Box 5.5. Inclusion of Verified Carbon Credits in Compliance Markets

As discussed in Section 4.1, some compliance markets, ETS systems, or carbon tax jurisdictions allow entities a limited volume of carbon credits toward their emissions obligations. Many of these jurisdictions, place constraints on the verification agencies which meet the quality requirements for carbon credits to count towards ETS obligations. For example, South Africa's carbon tax, the CORSIA ETS, and Colombia's carbon tax laws all allow carbon credits verified only by VERRA's VCS. In Singapore, entities regulated under the national tax system are allowed to purchase carbon credits verified by VERRA and Gold Standard.

Considerations in Verifying Carbon Credits

Verification of carbon credit projects involves an audit conducted by an agency to process the legitimacy of reporting data and activities and the final issuing of certificates. This involves several considerations which ultimately aim to ensure that the carbon credit guarantees the deliverable of offsetting the represented the unit of carbon and furthermore, that the offset does not count toward multiple carbon budgets.

Baseline and Additionality

Additionality refers to the notion that any benefits from carbon sequestration or reduction activities must be intentional and in addition to the removals which would have occurred without intervention, i.e., in the baseline approach. Setting a baseline, as discussed in Section 5.4. provides a point of reference of the offsetting activity in the absence of a targeted project. The sequestration of carbon into soil which would have not occurred without targeted implementation of carbon farming, that is, sequestration above baseline, can be issued as carbon credits. Additionality constrains market supply since carbon credits can only be issued for demonstrated performance improvements toward offsetting.

Additionality can be categorized depending on the contexts under which the offsetting activity takes place, e.g., additionality in consideration of existing policy instruments and regulation, industry standards, or international climate targets. Nonetheless, the various additionalities must be accounted for especially in compliance with the verification standards set by the governing bodies or independent private verifiers. For example, the US SEP practices a Performance Standard Test, a two-step common practice additionality assessment. The first step delivers a list of specific activities considered non-additional, and the second step allows projects to use specific measures to contest, with evidence, the non-additionality status of their activities. The activities considered non-additional by default include no-till, reduced till, cover-crop adoption, and rotational grazing, which are already adopted significantly in certain counties. Therefore, adopting such practices on an isolated farm in such regions is considered non-additional practice. However, projects may demonstrate their additionality by pairing a non-additional activity with at least one additional activity in each time frame, or project-specific analysis is submitted to justify the additionality of fields implementing tillage activities on the negative list.[202]

Double Counting

Prevention of double counting ensures explicitly that the gains of a carbon removal or reduction activity are not overstated by being accounted for multiple times and thus tries to ensure an accounting balance. Double counting will likely occur if multiple credits are issued for the same removal. Double use refers to the same credit being issued more than once, such as being retired more than once. Double claiming refers to the same carbon mitigation activity being counted by both the buyer and the seller.

Double counting exists even internationally, whereby improper accounting and verification of carbon credits results in countries counting activities' emissions reductions already sold via carbon credits toward their decarbonization targets.

Kazakhstan could consider two mechanisms to mitigate potential double-counting issues. First, it could implement a corresponding adjustment, whereby the number of reductions or removals claimed via buyers' purchase of carbon credits is removed from Kazakhstan's national GHG inventory and thus would not count toward the country's targets. However, there is a debate about whether corresponding adjustments stagnate development and investments in climate mitigation efforts by requiring countries to prioritize their accounting measures.[203] Alternatively, claims of carbon sequestration activities could be categorized into offset and contribution claims, whereby companies invest in enabling a country to achieve its NDCs through climate financing without making their claims by purchasing credits. This would be an advantageous opportunity for Kazakhstan in the initial stages of setting up an industry for carbon farming. Practical tools such as issuing a unique serial number for each carbon credit are also beneficial in reducing risks and increasing traceability.

Risk of Carbon Leakage and Reversal of Emissions

When credits are issued in ex-ante or for permanent sequestration, jurisdictional authorities remain under the obligation to monitor and tend to carbon storage, for example, by continuing incentives or assessments for farms to maintain their sequestered carbon. Also, jurisdictions at the national executive levels could benefit from administering reversal buffers. An emission is considered reversed if it is released back into the atmosphere before the end of the total storage consumption period, which can range from one year to over a century. However, fluctuations that do not reduce the carbon storage stock below the requirements of the issued credits are not considered reversed.

Meanwhile, leakage refers to the net change of emissions that occurs beyond the measurable and attainable removal activity. For example, if afforestation activities in one area increase deforestation activities in another area beyond the considerations of the project, this is considered a leakage. This form of leakage should be less concerning the regions under consideration in this report since these regions have no competing use for land. Leakages may also be caused by shifts in demand or supply, whereby the project reduces or increases the supply of another product which could induce an overproduction of specific goods in other countries, however, such leakages are not yet accounted for in most carbon market standards as they are difficult to measure. Lastly, ecological or naturally occurring leakages may be induced or accelerated by carbon farming activities such as competition for water resources, introduction of harmful or invasive species. The jurisdictional approach reduces the risk of leakages.

Risk of Reversal and Buffer Allocations

Buffers to address uncertainty and manage reversal risk are essential to creating carbon farming projects recognized by potential counterparts as a high-quality and high-integrity offset. The buffer guidelines may be developed by the relevant institutions governing the sequestration initiatives and registries and should ultimately instruct project stakeholders and participants on the handling uncertainty when estimating emissions reductions. The US SEP, Verra, ART TREES, Gold Standard, Regen Registry, and the Australian Carbon Farming Initiative all manage risk of reversals via buffer pools although with some variations in their nuanced implementation.

Broadly, these initiatives require project owners to allocate a certain percentage of carbon credits produced to a buffer pool instead of being sold. In case an avoidable reversal of sequestration occurs, the governing body cancels the project's allocations from the buffer pool to ensure the integrity of the registered credits.[204]

For example, under the Australian Carbon Farming Initiative, a risk of reversal buffer of 5% is applied to the output of all sequestration projects. This means that for every 100 tons of carbon sequestered, the project may only issue carbon credits representing 95 tons for projects with a permanence period of 100 years. For projects with a 25-year permanence period, a further 20% buffer is allocated.[205]

The uncertainty and risk assessment methodology should be tailored to the specific settings of carbon farming and crediting in Kazakhstan. As starting point, Kazakhstan could base its buffer allocations and thresholds on those which are in use by other countries, governments, or international organizations. Importantly, Kazakhstan could implement a buffer allocation if projects are structured on the basis of a longer permanence period, e.g., 25 years for sequestration of carbon through restoration of grasslands. Under carbon farming methodologies which guarantee a permanence period of less than 25 years, issuing temporary carbon credits (see Section 4.2) may be more suitable.

5.5 Non-Governmental Financialization of Carbon Farming

Early financialization is necessary to implement the research and development programs and engagement strategies which will drive the successful implementation of carbon farming. Revenues from carbon farming will only become tangible several years after implementation. For example, in current VCMs, carbon credits from emission reductions can be found with vintages of 2019 and 2020. Although forward contracts and options trading may some generate resources to cover upfront costs, international public and private investments, through international climate-finance institutions or multilateral banks could provide a vital source of funding to ensure robust development of early carbon farming schemes.

Kazakhstan must look outward for investment opportunities to kickstart the research, development, and implementation process of carbon farming. The blending of different sources of finance may create a synergy effect and amplify the ability of Kazakhstan to start and scale up the carbon farming program promptly. The amount of public and private investments and financial instruments available for climate-related projects has grown significantly in the last years. However, different financial instruments also carry certain risks and return expectations and provide the most benefit depending on the stage of the implementation.

Concessional financial instruments require below-market rate return on investments from the recipients. They are typically issued by financial institutions, large corporations, development banks or multilateral funds to support initiatives which support the acceleration of a regions' development. Concessional finance is allocated to high-impact projects such as climate change mitigation, water sanitation, or education which would not be supported by private financing alone.[206] Grants, concessional loans, and certain equity investments are all forms of concessional financing. Grants levy the fewest obligations return expectations on the recipient since grantees are not expected to provide a return on investment. Furthermore, grants can be allocated to riskier initiatives which means it serves as an initial source of financialisation for research and development or innovation of new projects.

Concessional loans expect a re-payment of principle and a return on investment, however, at a below market interest rate. First-loss guarantee, which allow third parties to compensate lenders if the primary borrower defaults on payments; and concessional equity investments which purposefully require fewer shares than the investment value, are also adjacent forms of concessional financing. Concessional loans are often a vital source of early financialization for new projects which are not yet ready to demonstrate their financial viability but can provide a 'proof of concept'. Similarly, concessional loans help to fund projects in their early stages of implementation.[207]

Meanwhile, non-concessional financing instruments such as market-rate loans and equity investments are important sources of investments for projects which are beyond their early establishment and have already shown signs of profitability. For market-rate loans in particular, collateral such as land may be given to lenders in case the borrower defaults on the repayment. Equity financing involves a transaction whereby the investor purchases a stake in the initiative and the payment finances the project with an expectation of future returns such as dividends on the purchased stake. The greater the associated investment risk, the higher the expected return for the investor. Beyond Value Chain Mitigation (BVCM) payments refers to private investments made by companies to mitigate or reduce emissions beyond their supply chains through, for example, purchasing carbon credits.[207] BVCM payments become feasible once the project is ready to commit to either ex-ante production of carbon credits or can issue ex-post carbon credits.

Box 5.6. Concessional Funds to Scale Renewables in Kazakhstan

In 2021, Kazakhstan announced that the country's renewable capacity had increased from 240 MW in 2015 to 1634.7 MW in 2020 and as of March 2021, the country had a total of 115 renewable projects with 1,310 fixed jobs and a further 3,000 temporary jobs creation recorded every year. The rapid scaling of Kazakhstan's renewable energy capacity was made possible through the targeted investment of US$ 55.5 million made by the Climate Investment Funds (CIF) supported by development funds from Australia, Canada, France, Germany, Japan, Spain, Sweden, UK, and US.

Between 2009 and 2016, the CIF engaged with Kazakhstan's government as well as the European Bank for Reconstruction and Development and the International Finance Corporation to lay the groundwork for scaling renewables including establishing feed-in tariffs, a renewable energy law, and setting purchase obligations for renewable energy for 15 years. In this period, grants were allocated toward constructing enabling conditions including capacity building and policy reforms which would facilitate a renewable energy market in the region. Then, project-based finances were deployed to developers in the form of 15- and 20-year concessional loans via the CIF's Clean Technology Fund with an interest of 1-2%.

The initial financialization helped scale the relevant projects to secure further funding of approximately US$ 200 million and later US$ 412 million which resulted in the total capacity for renewables growing to 542 MW and 284 MW by 2019 for solar and onshore wind power, respectively. The concessional financing enabled Kazakhstan to produce 9% of its total electricity from hydropower with a further 2.3% from various other renewable sources, helping the country to deliver on its NDC pledge to derive 3% of its energy capacity from renewables.[206]

Green Bonds and Sustainable Land Bonds

As climate related projects proliferate around the world, new and unconventional financial instruments have become more popular to channel funds to new climate-related technologies and initiatives either for a return on investment or for developmental purposes. A market for 'green' bonds has emerged. A green bond is an umbrella term referring to the financialization of projects with a specific environmental benefit. As with other bonds, borrowers such as national governments, jurisdictional agencies, or large-scale private organizations issue securities which are purchased by investors. The payment made by investors provides an early source of financing for the borrower, while the investor expects a return on their asset as the bond matures. The Green Bond Principles published by the International Capital Markets Association[208] provides a set of regularly updated voluntary criteria for issuers of green bonds to adhere to, such as reporting on the proceeds of the bond, designed to promote integrity and reliability in the market for green bonds.

Sustainable Land Bonds (SLBs) are a relatively new financial instrument specifically designed to raise capital for SLM projects and conservation practices, including carbon farming. They are long-term fixed-rate bonds issued by a government, government agency, or development bank and placed with investors in the mainstream international capital markets. This relatively new asset class aims to channel private capital towards SLM projects in many developing countries and encourage the transition to sustainable and low-carbon management practices at a larger scale.

SLB holds significant potential as an asset class that can effectively finance the extensive transition to sustainable and low carbon land management practices at various levels, including at the project level up to a country and even regional level. Unlike broader green bonds, which cover a broad range of environmentally beneficial projects, SLBs are tailored explicitly to financing land-based activities. Therefore, SLBs not only leverage the achievements of the green bond market but also takes a significant stride forward by establishing a clear connection to measurable outcomes, particularly in national emission reductions. Accessing financial instruments such as SLBs could provide Kazakhstan with a unique opportunity to scale its carbon farming and SLM practices with foreign investment and deepen its ties with stakeholders in climate mitigation and adaptation internationally.

The credibility of the SLBs, assessed by bond issuers, rating agencies, and underwriters, rests on selecting one or more performance indicators. These indicators must be relevant, measurable, verifiable, and be able to be benchmarked, e.g., as a percentage of emission reductions adoption of sustainable agricultural practices resulting in improved soil health, net carbon balance, land degradation neutrality, or other such LDN indications. Since SLBs are issued by government agencies, development banks, or multilateral funds, they are considered a reliable asset with low risk of default for individual buyers of the bonds. SLBs function and rank on par with other sovereign bonds with two key differences:

1. Proceeds are directed towards SLM initiatives aimed at reducing net GHG emissions,
2. The issuer enters into a long-term results-based payment (RBP) agreement with a third party, whereby the agreement is structured to either fully or partially offset annual interest payment on the SLB contingent upon attaining predetermined levels of land-based emission reductions within that particular year.

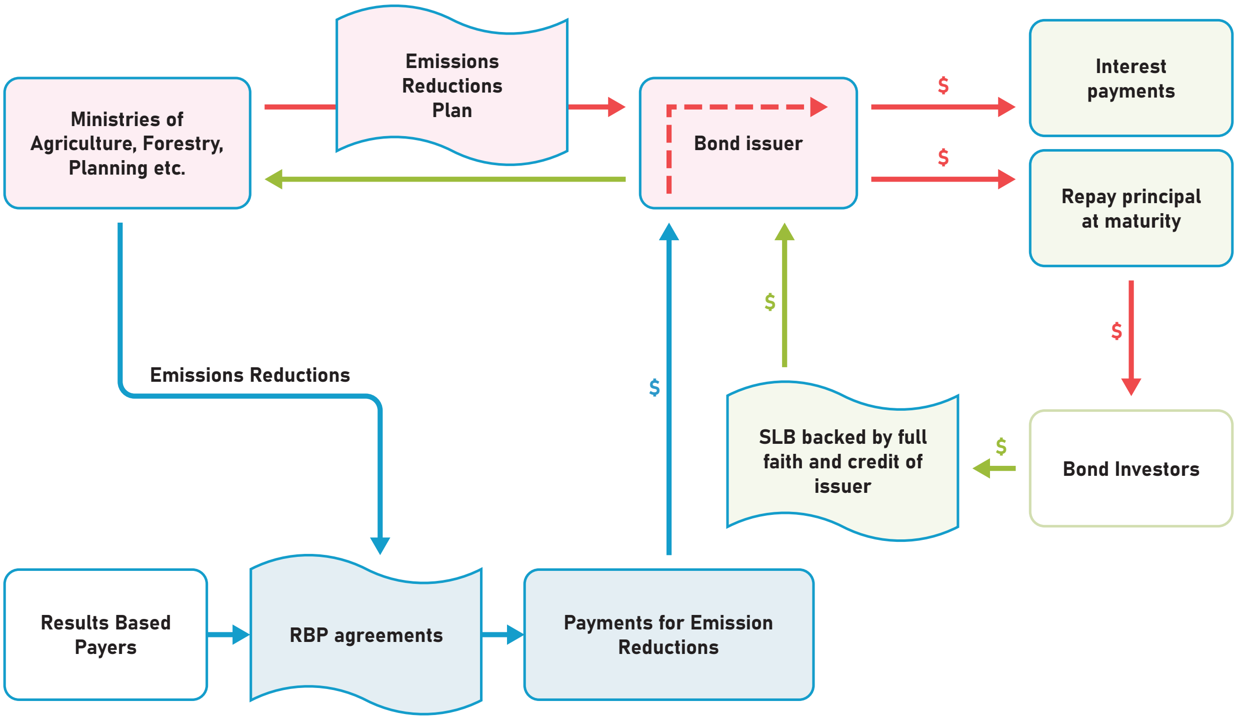


Figure 31. The financial pathways and institutions involved in an SLB process.
Source: A contributor's elaboration.

The processes involved in issuing SLBs is broadly presented in the illustration above to encompass various types of SLBs, different potential issuers of bonds, and consider diverse regulatory bodies and frameworks that support key performance indicators and sustainable performance targets. in a simplistic scenario, the ministries responsible for land-based projects such as carbon sequestration develop a detailed plan outlining how a project will contribute to emissions reduction or a form of SLM Plan and establish agreements with RBP payers who commit to paying for the results achieved by the projects. The bond issuer may range from government or quasi-sovereign entities to multilateral development banks or corporations. The bond issuer provides assurance to investors by providing full faith and credit backing to the SLB. Investors then purchase the bonds which funnels the initial capital to finance the specific land-based projects. RBP payers make payments to the government based on the actual results achieved by the land-based projects as per the KPIs linked to the SLM Plan. In the case of carbon credits, the role of MRV is critical to measure LDN outcomes and ensure results-based payments in the form of pre-purchased carbon credits. The bond investors receive periodic interest payments as a return on their investment and at the end of the bond's term (maturity), the issuer repays the principal amount to the investors, concluding the bond agreement.

Innovative financing mechanisms such as SLBs and dedicated funds offer a unique avenue for financing carbon farming projects in Kazakhstan. By attracting investments from a range of stakeholders, including institutional investors, impact funds, and green finance enthusiasts, SLBs can help to facilitate the funding needed to scale up such projects in Kazakhstan's rural areas and help realize their full potential without requiring unsustainable investments from local and national governments. In addition, the long-term nature of SLBs aligns well with the timeframes required for carbon farming projects to achieve significant carbon sequestration results. Typical maturities for SLBs would be between seven to over thirty years, in line with the maturities currently found for existing green bonds. This timeline also aligns with the initial requirements of investments in sustainable land development practice implementations. Future carbon assets could be used to back up insurance of carbon bonds issued by the national government.

Despite the rising popularity of green bonds and SLBs, there remains a lack of objective standardization.

The Green Bond Principles (GBP) are a voluntary set of principles and often green bonds can lack transparency of the use of collected proceeds or project development for the investors purchasing these bonds. Currently, industry effort is driving the momentum to standardize green bonds through various certification agencies, notably the Climate Bonds Initiative[209] and The Nature Conservancy.[210] Such agencies aim to address this gap by collaborating among each other with the goal to establish climate bonds certification standards specifically for the agriculture forestry and other land use sectors aiming to provide a framework for promoting sustainable land practices. Certification is a useful tool to meet the integrity and reliability expectations of investors.

By making concrete and visible statements of its intention to invest scale in its carbon farming practices, Kazakhstan could demonstrate its full backing which would also increase the attractiveness of potential SLBs for investors. This could attract RBPs that will allow risk sharing across the issuing country, investors, and results-based payers, while bringing down the cost of finance to the borrower[211]. The government's commitment to sustainable land use will catalyze additional investment in sustainable LDN, notably from the private sector. SLBs and RBP agreements ties in international support for sustainable land use from governments, lenders, NGOs, and private institutions and further catalyze domestic support by encouraging coordination between relevant government departments and engaging local stakeholders.

Lastly, Kazakhstan may consider the insurance of carbon-backed bonds and sovereign bonds. Recently, a new instrument called Carbon Backed Bonds (CBBs) has been proposed in conjunction with JREDD+. Unlike traditional green bonds that are supported by government or corporate budgets, the CBB relies on the financial success of green investment (see Box 5.7). CBBs have a comparative advantage relative to sovereign bonds since the CBB does not create an additional burden on the country's budget.[212,213] The CBB thus could relieve Kazakhstan from new financial obligations, however, given uncertainty about the future monetization of farmed carbon, potential buyers of CBB may perceive it as highly risky. This means that buyers will require steep discounts or higher coupon rates to purchase the bonds. The risks for buyers could be reduced if jurisdictions can acquire put options (see box 5.7) for anticipated carbon credits, which would give buyers the right to sell their carbon credits at a fixed price before the credits expires.

Box 5.7. An Example on how Carbon Backed Bonds (CBB) Could Work

Assume that by 2040, Kazakhstan can produce 10MtCO2 in emission removals through various carbon farming practices. Let us also assume that by 2040, the global price of carbon is approximately US$ 70/tCO2 and therefore, the total value of carbon credits is US$ 700 million. However, it remains uncertain whether carbon credits from carbon farming will be accepted on CCMs, or they will be traded solely on VCMs. To account for this, let us assume a probability of 0.6 for their integration on CCMs. In this case, the risk-adjusted value for the total production of carbon farming is US$ 420 million. Therefore, Kazakhstan may issue carbon bonds worth a total of US$ 420 million at maturity, subject to acceptance, price, and performance risks.

A put option is a contract that gives its holder the right to sell a number of equity shares at the strike price, before the option's expiry. If Kazakhstan can obtain put options on their credits, the price and acceptance risks may be mitigated. For example, Kazakhstan receives put options to cover 10 MtCO2 with a strike price of US$ 15/tCO2 expiring in 2040. Then it may issue almost risk-free carbon bonds worth at maturity US$ 150 million. If in 2040 the carbon price is higher than US$ 15 and instead is US$ 50/tCO2 sales at the carbon market receive US$ 500 million, and options expire. If the price is US$ 10/tCO2, the country exercises options and repays the debt.

Box 5.8: A Case Study on a Meghalaya Agroforestry Project by Earthbanc

With rising interests in carbon offsetting and climate mitigation initiatives, financial institutions dedicated toward funding climate-related projects are becoming increasingly popular. One example is Earthbanc, a financial technology organization renowned for their ambitions to finance NBS. Earthbanc's mission is to revolutionise carbon MRV through artificial intelligence technologies and exponentially grow VCM by scaling up NBS. Earthbanc has an official partnership with the UNCCD to help achieve the LDN global targets focusing through the restoration of 2.5 billion hectares of land by 2030.[214] To achieve these goals, Earthbanc works with tree planting projects to have their carbon sequestration audited and reported on accurately annually, in addition to finance and also agro-commodity market linkages.

One example of Earthbanc's activities is the Eric Bremley Lyngdoh Agroforestry Project, established in 2010 in Meghalaya, India, which addresses historical deforestation, soil erosion, and biodiversity loss.[215] Meghalaya, a global biodiversity hotspot, faces critical land degradation and declining agricultural productivity. The project aims to protect and preserve ecosystems, safeguarding natural forests and endangered flora and fauna. It also focuses on enhancing biodiversity, reforestation, carbon sequestration, and generating local socio-economic benefits. At its core, the project incorporates a strategic approach to carbon sequestration. Through the cultivation of 15,000 rubber trees (Hevea brasiliensis), the project mitigates climate change at the grassroots level. These mature rubber trees sequester approximately 100 kg of CO_2 annually in their 'Above Ground Woody Biomass'. This sequestration is sustained throughout the tree's life, contributing to long-term carbon capture. Additionally, the project introduced 100,000 pineapple plants (Ananas Comosus) in 2011-2012. These plants actively sequester carbon through their biomass. With a productive lifespan of 5-9 years, they continuously capture CO_2, further enhancing the project's carbon sequestration efforts.

The initiative also recognizes the importance of root carbon storage, which constitutes about 20% of the Above Ground Woody Biomass. This element not only supports soil health but also prevents erosion, a crucial factor for SLM. The rubber trees are harvested sustainably, ensuring a stable rate of CO_2 fixation. The harvested rubber retains its carbon for approximately 30 years in the product cycle before being released. This sustainable approach not only maintains consistent carbon sequestration but also allows for the creation of long-term carbon storage products like furniture. As trees reach the end of their productive life, they are replaced with new generations of rubber trees. This practice guarantees a continued high sequestration of carbon. The older trees, when used for long-term carbon storage products like furniture, contribute to the stable or increasing total carbon pool.

This comprehensive approach to carbon sequestration, integrated with SLM practices, not only advances carbon neutrality but also promotes environmental conservation and sustainable livelihoods within the region. The Eric Bremley Lyngdoh Agroforestry Project serves as a notable example of how targeted agroforestry initiatives can make significant contributions to global climate action and community well-being. By developing a scalable and holistic sustainable finance solution to provide upfront funding for land restoration projects, the goal is to create a network of productive agroforestry systems that also support agro ecotourism destinations connecting villages inhabited by different indigenous tribes with rich heritage and culture across the relatively unexplored northeast region of India and beyond.

Earthbanc proposes to issue new SLBs on its platform, whereby the SLB is a universal carbon credit pre-purchase agreement, that finances the creation of a carbon credit project helping monetise farmers increased tree and soil organic carbon from their SLM activities aligned with UNCCD LDN biophysical criteria. Earthbanc collaborates closely with private sector entities to secure funding for carbon credits, providing crucial upfront capital for project implementation. Furthermore, Earthbanc offers microloans to support alternative livelihoods, conducting thorough stakeholder analyses to align with project targets and ensure positive socio-economic impacts. Through these strategic financing mechanisms, Earthbanc not only drives environmental progress but also empowers local communities and economies, ensuring the long-term success of the agroforestry project.

Revolving Funds

Many activities that increase carbon sequestration generate net positive returns on investment even without monetization of farmed carbon. For example, the prevention of soil erosion prevents carbon emissions while also preventing the degradation of agricultural land. Intensification of cattle ranching and agroforestry prevents deforestation and pasture degradation, as another example.[212] However, despite such co-benefits, farmers may require immediate monetary incentives to develop carbon farming, which could be facilitated through granting farmers concessional loans. Loans taken by farmers could be repaid by deductions from their sale of carbon credits. The additional revenue streams may then be shared between farmers and jurisdictions, represented by executive agencies (Figure 32). The repayment of loans and trading of carbon credits generates a revolving capital that can support scaling up carbon farming. Setting up a revolving fund created on a jurisdictional level can help farmers overcome the financial hurdle of receiving loans that could be partially paid with the eventual selling of carbon credits. Options for revenue recycling may also be considered, including earmarking some tax revenues or creating a revolving fund.

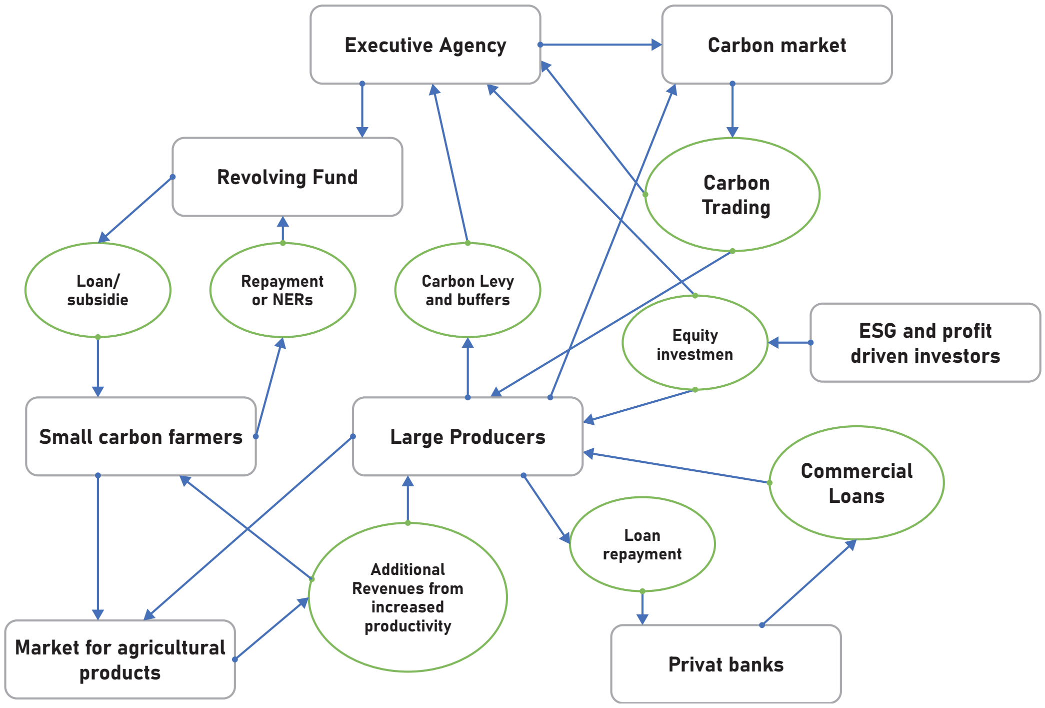


Figure 32. An illustration on the ecosystem of a revolving fund.
Source: A contributor's elaboration.

The revolving fund addresses the high cost of capital for small farmers. It provides a risk-sharing mechanism to help farmers overcome a cost trap and get involved in an emerging industry which farmers and other participants may otherwise perceive with greater risk. The executive agency could facilitate the management of a revolving fund according to the jurisdictional guidelines with the support of a trusted banking or accounting agency that can also manage micro-grants and administer the application of other financial incentives, helping the jurisdiction to launch and scale up the carbon farming program.

Box 5.9. Example: A Proposal on Regional Governance Structures for Carbon Farming Schemes for Italy

The Rete Rurale Nazionale, a network program supporting the integration of agricultural activities toward the development of Italy's rural regions (part of the broader European Rural Network), has devised a methodology for implementing district verification system for carbon farming in rural Italy. The methodology first identifies four types of stakeholders: i) higher authorities with scientific committees, ii) district governance bodies, iii) credit sellers, and finally iv) credit buyers. Then, the proposal applies a measure, avoid, reduce, compensate approach for every credit buyer. That is, to purchase 'sustainability credits' buyers must demonstrate their actions to reduce or avoid emissions beforehand such that only unavoidable emissions are compensated for through offsets. Third, the methodology highlights the role of governance structures in two forms: public registries and credit generation. Under public registries, the district authority applies a registry of projects and credits available publicly online. Each district manages their own registries; however, these should be transparent and comparable. Credits must also be traceable. Under credit generation, governing body conducts spot checks to ensure that the credits are produced with transparency and credibility, and that sold credits are retired as necessary.[216]

Box 5.10. The land Degradation Neutrality Fund: A mission-driven impact investment fund

The Land Degradation Neutrality (LDN) Fund, managed by Mirova,[217,218] an asset-management firm with investment solutions toward environmental and social impact, is a first-of-its-kind impact investment fund investing in profit-generating SLM and land restoration projects worldwide. The LDN Fund provides long-term financing (debt/equity) for sustainable land use projects that will reduce or reverse land degradation. It operates according to robust environmental and social standards, as per the comprehensive Environmental and Social Management System tools (ESMS) which aid organizations in incorporating environmental and social objectives into their activites using a clear set of defined and replicable processes.[219] The LDN Fund has secured over US$ 200 million worth commitments from investors, and uses a layered structure, leveraging public money to increase private sector investment in sustainable development. The public investors in the LDN Fund include Agence Française de Développement, European Investment Bank, Global Environment Facility, the Government of Canada, and The Department for Environment, Food and Rural Affairs of the UK. The Private Investors include Allianz, BNP Paribas, Natixis, FondAction, Fondation de France, and L'oreal.

The LDN Fund[220] finances those land restoration and sustainability projects which can become financially viable and self-sufficient in the long run as well as show the potential to generate financial returns for investors and shareholders.[217] It strategically allocates resources towards projects and initiatives that target the restoration and rehabilitation of degraded land and foster the widespread adoption of SLM practices. By doing so, the LDN Fund endeavors to fortify the provision of vital ecosystem services, ensuring the long-term health and productivity of critical terrestrial ecosystems. In addition to providing financial resources, the LDN Fund operates a Technical Assistance facility as an integral component of its project financing process. The technical assistance facility plays a crucial role in bolstering project success by offering expertise, guidance, and capacity-building support to project proponents. By combining financial backing with targeted technical assistance, the LDN Fund maximizes the impact of its investments, fostering a collaborative and inclusive approach to combating land degradation and advancing the goal of land degradation neutrality.

The process through which the Fund finances projects involve several key steps. Initially, project proponents submit proposals outlining their objectives, methodologies, and anticipated outcomes in line with the LDN Fund's mission of combating land degradation. These proposals are rigorously assessed based on criteria such as environmental impact, feasibility, and alignment with SLM practices. Once a project is selected, the LDN Fund provides financial support through a combination of investment capital, grants, and concessional finance, tailored to the specific needs and circumstances of the project. Throughout the project's implementation, the LDN Fund maintains an active role in monitoring progress, ensuring adherence to agreed-upon milestones, and offering technical expertise and support as necessary. This iterative process of proposal evaluation, funding allocation, and ongoing project management allows the LDN Fund to effectively mobilize resources towards initiatives that contribute to the restoration and rehabilitation of degraded land, ultimately promoting SLM and the enhancement of ecosystem services.

6. Understanding the Broad Impacts and Implications of Carbon Farming in Kazakhstan

Our report has provided a comprehensive overview of carbon farming as a new pathway with emerging opportunities to benefit from the international arena of carbon markets and champion Central Asia toward the global climate agenda. By investing in a carbon farming program on a national scale, Kazakhstan can benefit by reviving unused land endowments toward sustainable agriculture through land restoration and soil carbon sequestration with improved well-being of its citizens, attracting interest from international investors seeking trustworthy carbon credits from offsetting programs striving NBS, and strengthening its own LEDS 2060 strategy and contributions toward global climate change mitigation efforts, UN SDG targets, and beyond.

Given its efforts in scaling up carbon farming practices and NETs, Kazakhstan has marked potential to impact global carbon emissions. Alongside the soil-based and agricultural sequestration methods discussed in Chapters 1 to 3, Kazakhstan has also invested in other NBS such as increasing the country's forest cover to 20% by concerted reforestation efforts by 2050 and promoting LDN by 2040.[221] The country has been exploring other NET technologies, such as CCS, BECCS, and DAC. It also benefits from new and innovative financial instruments and mechanisms, including global funds such as GEF and Green Climate Fund, blended financing, and private investments for reducing its carbon footprints.

The final chapter of this report summarizes the national, regional, and global impacts that an effective carbon farming program can bring about in Kazakhstan. Furthermore, by sharing its experience to promote and scale up the best technologies, practices, policies, and partnerships, Kazakhstan can accelerate progress toward a low-carbon future and create capacity for sustainable economic growth worldwide.

6.1. The Concept of Co-Benefits

In the current environment characterized by limited public budgets and fiscal frugality, long-term structural governmental interventions are difficult to implement or unpopular despite eventual rewards. Hence, it is imperative to focus that resources are allocated toward policy and programs that capacitate economic viability and generate synergistic beneficial dividends or co-benefits. Co-benefits refer to the symbiotic effects of one action providing a cost-effective solution to multiple objectives as opposed to potentially overlapping actions that pursue singular objectives. For example, the World Bank describes climate co-benefits as the share of financing dedicated to climate action, enabling development objectives.

Co-benefits enable governance to tackle two key challenges policymakers face in implementing ambitious climate-related actions. Firstly, climate change poses a significant long-run threat to populations worldwide. However, climate-relation actions require forward-looking investments on a long-term basis and are often undermined in favor of policies with immediate positive outcomes. The presence of tangible, short-term co-benefits can increase the prioritization of climate change mitigation actions for both populations and policymakers. For example, the EU's roadmap for a low-carbon economy by 2050[222] justifies substantial investments into the transition by the expected creation of new jobs, the forecast reduction of energy imports, and the foreseeable gains in air quality and health. Such benefits create local, short-term positive outcomes for entities that may bear some cost of the implementation e.g., taxpayers.

Thus, the notion of co-benefits has become crucial for climate-mitigation policies whereby the expected dividends of policy action are otherwise observable and likely at an inter-generational timescale.

Secondly, local, national, or multi-national co-benefits may help overcome the 'tragedy of the commons' challenge. As discussed in Chapter 4, climate mitigation efforts are widely considered a global public good, whereby the investments made by a jurisdiction or country ultimately benefit all countries in a non-exhaustive manner, i.e., non-rivalrous, and without excluding populations, i.e., non-excludable benefits. Though climate-related actions also benefit those who bear the cost, there is also an incentive for free-riding.[168] In such a setting, undertaking a globally coordinated approach to climate mitigation is difficult. Co-benefits at the jurisdictional or country level thus provide additional benefits of mitigation actions, new entry points for mitigation policy making, and increase to formalize these climate-related actions through engaging in international agreements and commitments.[223]

Particularly in recognition of this fact, there is growing interest in implementing climate mitigation policies where co-benefits can be earmarked within the wider climate-related framework of objectives.[223] For example, Kazakhstan's LEDS 2060 Strategy discusses several co-benefits, which include increasing FDI flows into the country, enhanced technological developments and competitiveness, new employment opportunities, and improved well-being of the population.[30] Such trends are also observable in advanced economies such as the US, where evidence of co-benefits is being used to argue for the expansion of municipal-scale climate actions.[224] Furthermore, in China, local implementation of climate plans is strongly tied to local incentives for energy efficiency.[225–227] India's National Action Plan on Climate Change explicitly states that it is driven by co-benefits, understood as development actions that also bring climate gains.[228] In Brazil, a robust climate policy is strongly associated with domestic breakthroughs in forest policy.[229]

Synergistic outcomes may also refer to multiple negative outcomes from climate-related investments and policies referred to as disbenefits or co-costs. For example, increased use of energy from biomass helps reduce GHG emissions (to the extent the biomass pool is managed sustainably) but can, in some cases, have adverse side effects in terms of increased competition on agricultural land or loss of biodiversity.[223] In fact, the existence of co-impacts, that is, co-benefits and co-costs, is unsurprising because, in most cases, GHG emission reduction cannot occur while keeping everything else.[223] Carbon sequestration, for example, may be expected to make systemic impacts well beyond GHG emission reductions. Furthermore, it requires changes in the behaviors of households and firms with complex outcomes. Depending on how carbon sequestration is achieved, there is an opportunity cost of land and water use, financial allocations, and human capital elsewhere. By understanding co-costs and co-benefits, policymakers can best assess actions that fit their priorities.

6.2 A Context of the UN SDGs

The 17 UN Sustainable Development Goals (SDGs; Figure 33) is an internationally recognized framework that provides a set of targets that cover the economic, social, and environmental dimensions of sustainable development.[230] They were adopted in 2015 by the 193 countries of the UN General Assembly as part of the Post-2015 Development Agenda via a resolution called 2030 Agenda (more commonly referred to as Agenda 2030). The UN SDGs serve both as enablers (means) and indicators (ends) of human rights. For example, SDG 2 Zero Hunger aligns with economic human rights, while SDG 8 Decent Work and Economic Growth and SDG 9 Industry, Innovation, and Infrastructure offer ways to ensure that the economic and social rights of citizens are fulfilled.

The SDG framework includes 169 targets and 247 indicators.[231] The rankings provided by the Sustainable Development Report 2023 measures a country's overall progress toward achieving all UN SDGs assuming all goals have equal weights.

Currently, Kazakhstan ranks 66 (out of 166 countries included in the ranking) with the greatest progress attained for SDG 1 No Poverty, while stagnating progress on SDG 2 Zero Hunger, SDG 7 Affordable and Clean Energy, and SDG 15 Life on Land.[232] Hence, it is imperative for the national government to identify viable measures to enhance its advancement toward achieving SDGs.

In the context of carbon farming, of particular relevance is SDG 15 Life on Land. The UNCCD raised concerns on the sluggish implementation of SLM practices[233] and proposed the integrating Land Degradation Neutrality (LDN) targets as part of the UN SDG framework. The concept of LDN was first raised at the Rio+20 conference of the United Nations and recorded in the resulting document The Future We Want.[233] "We recognized the need for urgent action to reverse land degradation. In view of this, we will strive to achieve a land-degradation neutral world in the context of sustainable development." The LDN aim is now fixed in SDG 15 as follows: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The relevant target 15.3 of this goal is as follows: "by 2030, combat desertification, and restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land-degradation neutral world".[234]

Figure 33. UN Sustainable Development Goals.
Source: United Nations.

SDGs provide a structured set of priorities that can help policymakers decipher and evaluate potential positive and negative synergistic outcomes from various policies including climate policies such as carbon farming programs. Figures 34 and 35 illustrate the potential for systemic co-impacts of carbon farming and sequestration by soils across a diversity of SDGs on an aggregate basis using the SDG Mapper, a text-mining tool developed by the European Commission's Joint Research Center.[235] The most pronounced co-impacts, unsurprisingly, are found with respect to SDG 13 Climate Action, SDG 15 Life on Land, and SDG 2 Zero Hunger.

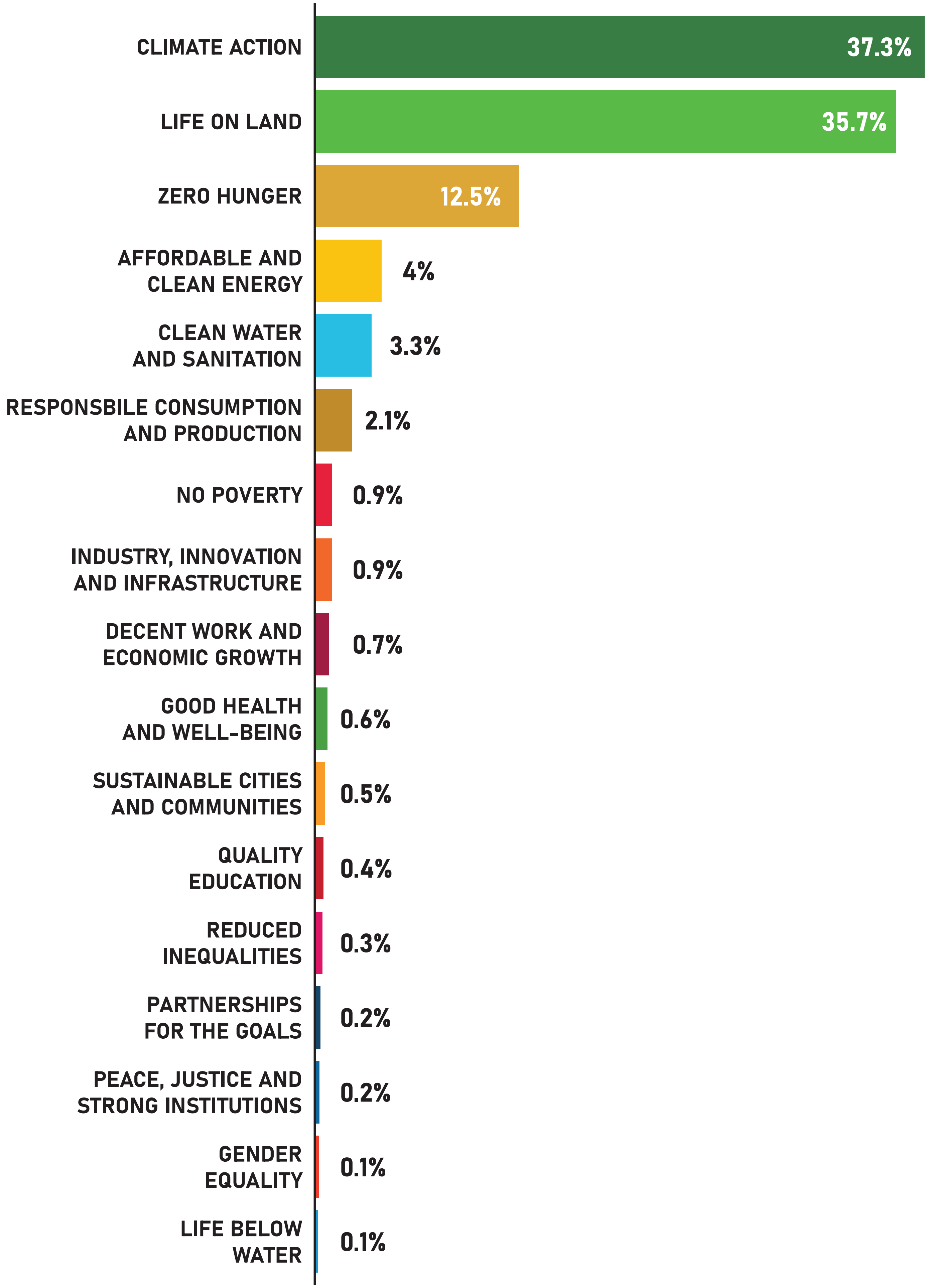


Figure 34. The proportion of research articles published in English and indexed in SCOPUS having relevance to each SDG; a total of 33 articles included in this analysis as a result of a search which used the keywords ‘carbon-farming’ and ‘impact’ in their title,
Source: Obtained using SDG Mapper (European Commission, 2023).

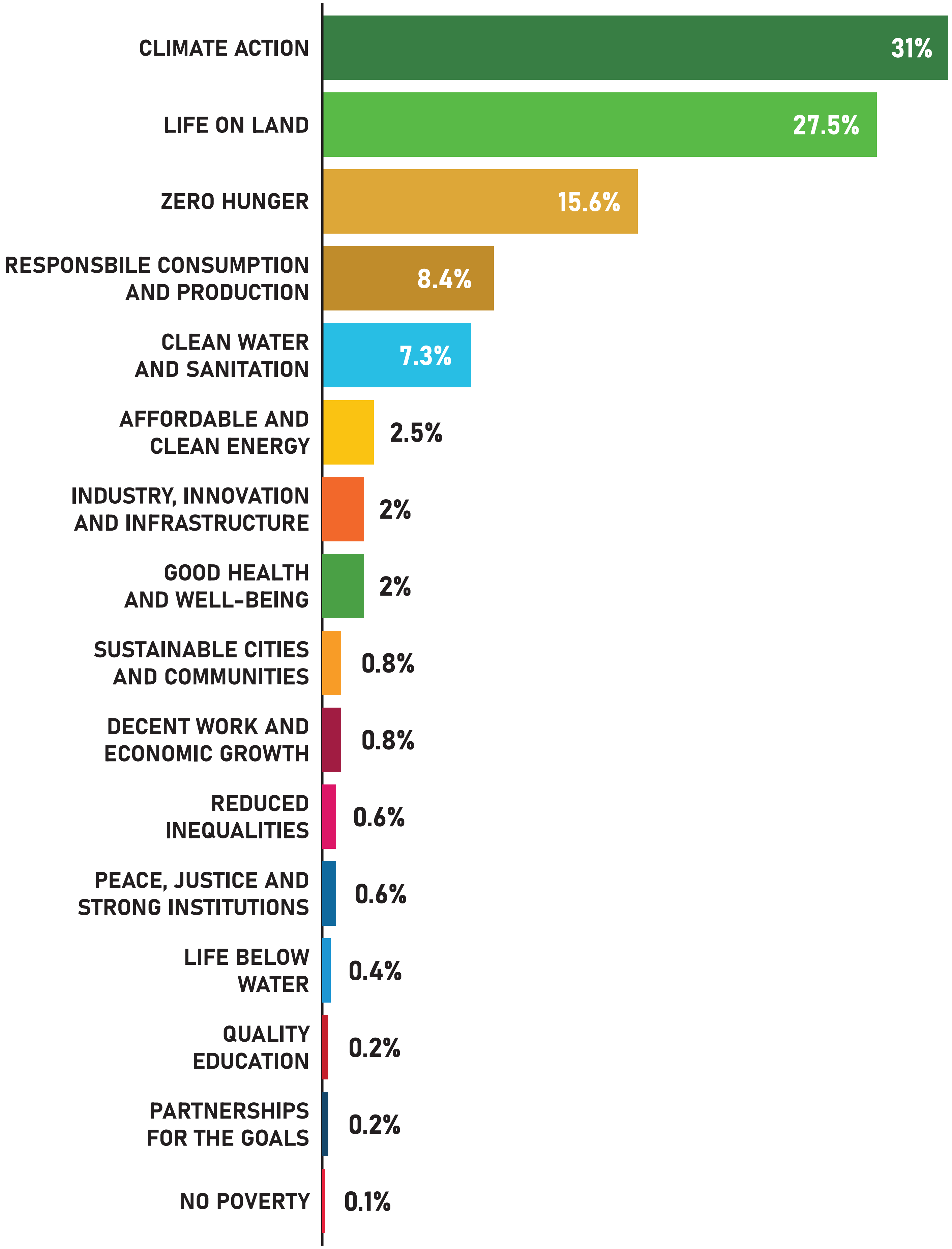


Figure 35. The proportion of research articles published in English and indexed in SCOPUS having relevance to each SDG; a total of 74 articles included in this analysis as a result of a search which used the keywords 'soil' AND 'sequestration', 'impact', and 'agriculture' in their title, abstract, or under keywords.
Source: Obtained using SDG Mapper (European Commission, 2023).

6.3. Discerning Economic, Social, and Environmental Co-Benefits of Carbon Farming for Kazakhstan and the ADB Region

Chapters 4 and 5 largely focus on the monetizing of opportunities of carbon farming through the trading of carbon credits, which can generate new incomes for farmers and rural communities. Beyond that, an array of other monetizable and non-monetizable benefits are associated with carbon farming which creates a foundation for mobilizing various sources of finance to initiate carbon farming programs.

Although an evaluation of the exact co-benefits to be derived from the implementation of carbon farming in the specific context of Kazakhstan and the ADB region requires focused research, which is beyond the scope of this report, the comprehensive literature review underpinning this report suggests that carbon farming has the capacity to eventually become an economically viable activity largely independent of public budget support and deliver short-term co-benefits that increase the social and economic well-being of citizens and the quality of environment (Figure 36).

Soil carbon management and sequestration, the core carbon farming approach discussed in this report, have been shown to deliver co-benefits that align with the ambitions of the various UN SDGs, which can help to build a political, financial and technical momentum to address these goals.[237] Increased soil carbon storage through soil carbon management in terrestrial ecosystems also has wider benefits due to improvement of water quality and soil, and land restoration through improved fertility and biodiversity restoration making a positive impact on biodiversity protection, enhanced food security, and mitigation of climate change.[238,239]

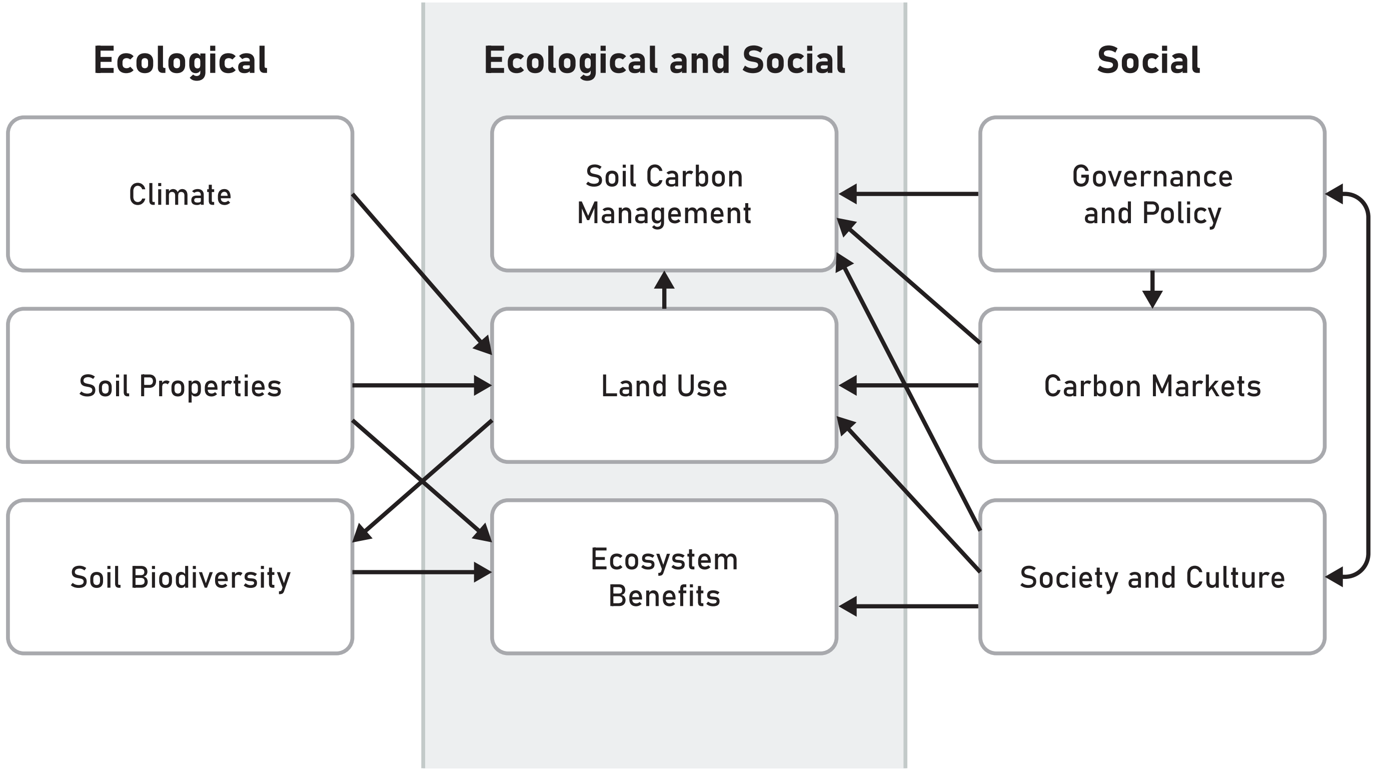


Figure 36. Schematic illustration of the main systems involved in carbon farming and driving co-benefits.
Source: Amin et al (2020).

Implementing climate mitigation activities may become less challenging if potential co-benefits incentivize the participation of various stakeholders. As such, co-benefits of carbon farming can catalyze farmers' motivation to take on SLM practices and soil sequestration activities, although this also depends on the stakeholders' existing welfare and the attainable co-benefits. For example, forestland owners in parts of the US have been shown to express a greater interest in the co-benefits of afforestation than just the income from carbon credit sales.[240] In the case of Kazakhstan and neighbouring countries, such environmental co-benefits and revival of agricultural land and, ultimately, future agricultural commerce may be a significant motivation for farmers to adopt carbon farming.

Depending on the specific methods implemented, carbon farming can provide significant environmental co-benefits. Carbon sequestration can increase soil fertility and water retention and reduce soil erosion to prevent severe land degradation, with evidence presented throughout this report. Planting diverse cover crops, creating buffer zones, and adopting agroecological approaches can provide a habitat for beneficial insects, birds, and other wildlife, which helps protect and promote biodiversity within agricultural landscapes, contributing to the conservation of native species and ecological resilience. Hypothetically, the restoration of ecosystems can further develop into a monetizable benefit since by adopting carbon-friendly practices, farmers and rural entrepreneurs can leverage co-benefits in carbon credit markets, participate in eco-tourism initiatives, or access funding for sustainable agriculture projects.

Furthermore, erosion protection may also create indirect non-monetizable economic benefits captured by farmers and external health benefits by reducing dust storms and health damage from exposure to PM2.5 pollution.[241,242] Such multiple benefits from, and positive externalities of, carbon farming can further incentivize respective cost-effective state support measures. Inter alia, it may require policymakers to subsidize early take-up of carbon farming which can be gradually phased out as demand and revenues from trading carbon credits grows.

The impact of Kazakhstan's efforts to promote carbon farming and NETs can be scaled across the ADB region, and Kazakhstan's program can serve as valuable insights and learning opportunities for other countries striving to achieve their climate targets. Sharing best practices, technological advancements, and research findings can facilitate the replication and scaling of effective approaches globally. By aligning these initiatives, Kazakhstan can also optimize its land use practices, promote regenerative agriculture, enhance carbon sequestration, and minimize land degradation. This would lead to a more effective and efficient pathway toward achieving national and international climate and environmental goals at the regional and global levels. Additionally, carbon farming can provide a platform for partnerships with regional and international research institutions, participation in international conferences, and joint policy initiatives with neighbouring countries. This can foster diplomatic alliances that may become critical toward representing joint climate-related and diplomatic interests of ADB countries in the international arena.

Importantly, to implement and sustain climate mitigation measures such as carbon farming on a regional scale, collaboration of the ADB countries could play a pivotal role to help address various transboundary issues. For example, water stress is a significant cause of concern for the entire Central Asia. In Kazakhstan, approximately half of its water supply is runoff originating from its neighbouring countries.[243] Agriculture ranks the highest annual use, which accounts for the country's greatest share of total water withdrawal, out of which almost all of the water is taken from surface sources. Without addressing water-stress, Kazakhstan cannot reach its full capacity for carbon farming as it may increase the complexity of water stress in this region. Thus, coordination among stakeholders of relevant countries for implementation of these agreements is the key to ensure water supply.

With the increase of population and economic development, Central Asia has become an essential source of grain and food for the world. Yet, projections show that by 2040, only 50% of the regions' water demand could be met.[244] The water deficiency in this region may ripple crises into all water dependent economic sectors across the ADB and result in stagnant economic growth throughout Central Asia. since it threatens to reduce agricultural productivity and food security which could subsequently create severe poverty and malnutrition risks. Water stress and land degradation may only worsen without efficient collaborations between ADB countries to manager their resources and jointly conduct climate-related activities.

Another transboundary issue across the ADB region is related to soil erosion caused by dust and sandstorms. Almost 50 % of the land of Kazakhstan has an annual average wind speed of 4-5 m/s and the highest speed reaches 6 m/s or more. The heaviest winds usually happen in the flat parts of the country, combined with cold intrusions from Siberia in spring and autumn seasons, bringing a substantial risk of erosion.[241] A lack of land cover and exploitation of water resources have led to frequent droughts, and the strong wind and rich sand and dust sources in this region heightens the risk of dust and sandstorms across boundaries. The increase in the frequency and severity of drought coupled with rising temperatures in the last decade pose a significant risk to damaging soil sequestration efforts. Since this a problem faced by several countries in the ADB region, transferring knowledge, practices, and technologies will increase efficiency and drive synergistic innovations for all ADB countries in combatting such issues.

Broadly, three key aspects must be addressed for Kazakhstan and the ADB region to combine efforts for climate-change mitigation through carbon farming. Firstly, breaking the silos between the ministries, departments, and agencies would ensure integrated resource management and sustainable use of land, water, bioenergy, and other natural resources, both within Kazakhstan and between ADB countries. This integrated approach promotes the efficient use of resources, minimizes overlaps, and enables a holistic and balanced approach to ensuring maintained SLM and LDN scalability. Secondly, ensuring that carbon farming practices, research, and policies are accurately documented to facilitate knowledge transfers. By documenting successful experiences and lessons learned under carbon farming, Kazakhstan can identify and promote best practice models that have proven effective in achieving carbon sequestration, land degradation neutrality, and negative emissions. This exchange of knowledge and experiences with other countries and regions can contribute to global efforts in addressing climate change and promoting SLM practices.

Lastly, a supportive and regulatory framework is critical for successfully implementing carbon farming in Kazakhstan, and beyond. Clear guidelines, targeted incentives, smart policies, and market mechanisms must be set can incentivize farmers and businesses to adopt relevant practices which can be scaled up in the region. A robust governance structure is essential to monitor and verify emissions reductions, address potential trade-offs, and ensure effective implementation of carbon farming and NETs that can be replicated regionally and globally.

Conclusion

Our report has provided a comprehensive summary of the key considerations for Kazakhstan in developing a national carbon farming strategy that could usher in new economic prospects, social improvements, and environmental restoration, as well as strengthen the country's standing in international markets and efforts. The underutilized, aggravated endowments of Kazakhstan's steppes and semi-deserts can be transformed into a valuable asset as a high-capacity carbon sink through functional carbon farming practices. As discussed in Chapter 2, there are several climatic challenges in Kazakhstan; however, overcoming these challenges through carbon farming could drive the country's efforts in decarbonizing its economy and impact global net zero targets by enhancing carbon sequestration potential in its AFOLU sector. As Chapter 3 shows, by promoting carbon farming practices such as cover cropping, reduced tillage, agroforestry, and improved land management practices, Kazakhstan can achieve its potential SOC of up to 35 $MtCO_2e$/year which would deliver negative emissions given its current 32 $MtCO_2e$/year emission level.

Beyond the country's own decarbonization ambitions, as Chapter 4 discusses, Kazakhstan already benefits from its operational ETS scheme which provides a useful proportion of infrastructures and knowledge required in building an industry around the trading of carbon credits. Both VCMs and CCMs have become critical to emission reduction strategies, and despite their limitations, both are projected to grow seismically. Between 2020 and 2021, carbon credits generated from forestry and land use, dominated by REDD+ project sequestration, quadrupled (and accounted for 46% of the total traded volume) globally. Yet, global trading of carbon derivatives is far from reaching its peak, and the trade volume for offsetting carbon credits is likely to expand. The IPCC estimates that at least 3.8 billion tons of permanent CO_2 removal are needed annually by 2050 to limit global warming to 1.5°C. However, the current rate of CO_2 permanently removed from the atmosphere is less than 10,000 tons.

Given the huge potential, Kazakhstan's active participation in carbon trading schemes, innovative financial mechanisms, and public-private partnerships will generate a significant global impact in the fight against climate change. As discussed in Chapter 5, Kazakhstan's engagement in innovative financial mechanisms, such as green bonds, climate funds, and carbon offset projects, can mobilize climate finance from public and private sources. Unlocking private sector finance can support implementing SLM projects and initiatives within Kazakhstan and other countries facing similar challenges. By mobilizing climate finance from the private sector, Kazakhstan will support global climate change mitigation and adaptation efforts. Furthermore, soil sequestration methodologies and MRV assessments developed in Kazakhstan could advance scientific research and understanding of the best practices for soil carbon sequestration, SLM, and land restoration management worldwide.

As Chapters 5 and 6 show, carbon farming and NETs have significant social and economic benefits at the national and global levels. Local communities' involvement, land rights, and equitable access to benefits can avoid unintended consequences and ensure a just transition to a low-carbon economy in Kazakhstan. Environmental assessments, biodiversity conservation, and safeguarding against potential negative impacts are vital to maintaining the ecological integrity of the carbon-intensive economy of Kazakhstan. The success of business models, sustainable supply chains, and the creation of jobs on account of the adoption of carbon farming practices in Kazakhstan will have a significant impact at the global level. Kazakhstan's efforts to promote carbon farming and NETs align with the SDGs.

The promotion of carbon trading schemes, innovative financial mechanisms, and public-private partnerships would support multiple SDGs, particularly Goal 13 Climate Action, SDG 15 Life on Land, and SDG 2 Zero Hunger. By contributing to these global goals, Kazakhstan enhances its role as a global champion and accelerates progress towards a sustainable future.

Overcoming technical, economic, and policy challenges while considering social and environmental aspects will be crucial for successfully implementing carbon farming technologies and practices at the national level, which can be replicated and scaled up at the global level. Carbon farming alone cannot promise to resolve of the potentially devastating impact of climate change; however, it provides a pathway toward the right direction.[245] Carbon farming, as defined by this report, delivers a solution for countries to implement which is economically viable and executable sooner than most technological advancements for carbon removal. Furthermore, the benefits of carbon farming extend beyond carbon removal; if implemented effectively, carbon farming can help to address land and ecosystem degradation, food security issues, and simultaneously generate new livelihoods and welfare opportunities for communities and populations in Kazakhstan and across the world.

References

---

1. UNFCCC. Nationally determined contributions under the Paris Agreement, FCCC/PA/CMA/2022/4 (2022).
2. IPCC. Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (2022) doi:10.1017/9781009325844.
3. UNCCD. UNCCD Data Dashboard Kazakhstan. https://data.unccd.int/ https://data.unccd.int/country-overview?country=KAZ&layer=VOLUNTARY_TARGETS#country-profile-map (2023).
4. Republic of Kazakhstan. PRAIS4 National Report. https://reporting.unccd.int/api/country/KAZ/report/official/pdf (2023).
5. Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan, United Nations Development Programme in Kazakhstan, & Global Environmental Facility. Eighth National Communication and Fifth Biennial Report of the Republic of Kazakhstan to the UN Framework Convention on Climate Change. (2022).
6. Lebed, L. Possible changes in agriculture under the influence of climate change in Kazakhstan. in An Overview of Environmental Issues in Central Asia (eds. Qi, J. & Evered, K.) 149–162 (Springer Netherlands, 2008).
7. Duenwald, C., Abdih, Y., Gerling, K. & Stephanyan, V. Feeling the Heat: Adapting to Climate Change in the Middle East and Central Asia. (IMF, 2022).
8. UNESCAP. Kazakhstan climate change and disaster risk profile. https://www.unescap.org/kp/2022/kazakhstan-climate-change-and-disaster-risk-profile (2022).
9. IPCC. Summary for Policymakers. In Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (eds. Masson-Delmotte, V. et al.) (2018).
10. World Bank Group. Kazakhstan Country Climate and Development Report (World Bank, 2022). doi:10.1596/38215.
11. Arneth, A. et al. Framing and Context. in Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (eds. Shukla, P. et al.) (2019).
12. Green, C. & Byrne, K. A. Biomass: Impact on Carbon Cycle and Greenhouse Gas Emissions. in Encyclopedia of Energy 223–236 (Elsevier, 2004). doi:10.1016/B0-12-176480-X/00418-6.
13. Terrer, C. et al. A trade-off between plant and soil carbon storage under elevated CO2. Nature **591**, 599–603 (2021).
14. Babiker, M. et al. Cross-sectoral perspectives. in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Shukla, P. et al.) (Cambridge University Press, 2022).
15. UNFCCC. Information note. Removal activities under the Article 6.4 mechanism. (2023).

16. World Bank. State and Trends of Carbon Pricing 2023. (World Bank, 2023). doi:10.1596/39796.

17. Shishlov, I., Morel, R. & Bellassen, V. Compliance of the Parties to the Kyoto Protocol in the first commitment period. Clim. Policy **16**, 768–782 (2016).

18. Australian Government Department of Environment and Energy. Requirements for using the Full Carbon Accounting Model (FullCAM) in the Emissions Reduction Fund (ERF) methodology determination: Carbon Credits (Carbon Farming Initiative) (Native Forest from Managed Regrowth) Methodology Determination 2013. (2017).

19. Department of Primary Industries and Regional Development, A. Carbon farming: reducing emissions through savanna fire management – Australia. Government of Western Australia Department of Primary Industries and Regional Development https://agric.wa.gov.au/n/1684 (2023).

20. Woodland Carbon Code. Home - UK Woodland Carbon Code. Woodland Carbon Code UK https://woodlandcarboncode.org.uk/ (2019).

21. Rolinski, S. et al. Dynamics of soil organic carbon in the steppes of Russia and Kazakhstan under past and future climate and land use. Reg. Environ. Change **21**, 73 (2021).

22. Sanz, M. et al. Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. (2017).

23. FAO. Conservation Agriculture. https://www.fao.org/3/i7480e/i7480e.pdf (2017).

24. European Commission, Radley, G., Keenleyside, C. & Frelih-Larsen, A. Technical guidance handbook: setting up and implementing result based carbon farming mechanisms in the EU : executive summary. (Publications Office of the European Union, 2022).

25. Estim, A., Shapawi, R., Shaleh, S. R. M., Saufie, S. & Mustafa, S. Decarbonizing Aquatic Food Production Through Circular Bioeconomy of Aquaponic Systems. Aquac. Stud. **23**, (2022).

26. FAO. Farmers stop ploughing on Kazakhstani steppe. FAO website https://www.fao.org/conservation-agriculture/case-studies/kazakhstan/en.

27. Nurbekov, A. et al. Adoption of Conservation Agriculture in Central Asia. (2022) doi:10.19103/AS.2021.0088.11.

28. Republic of Kazakhstan. Landscape Restoration Project: Environmental and Social Management Framework. https://www.gov.kz/uploads/2020/11/24/8d402c995e51eef51994b3e2a0856774_original.1797102.pdf (2020).

29. Kazinform. Первый карбоновый полигон появился в Казахстане. Казинформ https://www.inform.kz/ru/pervyy-karbonovyy-poligon-poyavilsya-v-kazahstane_a3999338 (2022).

30. Republic of Kazakhstan. Strategy to Achieve Carbon Neutrality to 2060. approved by Decree of the President of the Republic of Kazakhstan No. 21 dated 2 February 2023.

31. Carbon Pricing Leadership Coalition. Carbon Pricing Leadership Coalition. Leadership Report 2017- 2018. (2018).

32. WOCAT. WOCAT Creation of a perennial grass seed area (CACILM) (Kazakhstan). (2019).

33. FAO. A protocol for measurement, monitoring, reporting and verification of soil organic carbon in agricultural landscapes. (FAO, 2020). doi:10.4060/cb0509en.

34. Raes, L., Mittempherger, D., Piaggio, M. & Siikamäki, J. Nature-based Recovery can create jobs, deliver growth and provide value for nature. (2021).

35. UNCCD. Restored Land, Healthy People, Green Recovery. 10 https://www.unccd.int/sites/default/files/inline-files/UNCCD_Solution%20Brief.pdf (2021).

36. Arias, P. et al. Technical Summary. in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Masson-Delmotte, V. et al.) 33-144 (Cambridge University Press, 2021). doi:10.1017/9781009157896.

37. Myhre, G. et al. Anthropogenic and Natural Radiative Forcing. in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Stocker, T. et al.) 659-740 (Cambridge University Press, 2013).

38. IPCC. Summary for Policymakers. in Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Masson-Delmotte, V. et al.) (2021). The term 'likely' denotes a probability of 66 to 100%, 'very likely' — a probability of 90 to 100%.

39. UNFCCC. Parties to the United Nations Framework Convention on Climate Change. https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states.

40. Maamoun, N. The Kyoto protocol: Empirical evidence of a hidden success. J. Environ. Econ. Manag. **95**, 227–256 (2019).

41. UNFCCC Conference of the Parties. Report of the Conference of the Parties on its fifteenth session, held in Copenhagen from 7 to 19 December 2009. Addendum. Part Two: Action taken by the Conference of the Parties at its fifteenth session (FCCC/CP/2009/11/Add.1). (2010).

42. Armstrong McKay, D. I. et al. Exceeding 1.5°C global warming could trigger multiple climate tipping points. Science **377**, eabn7950 (2022).

43. Fankhauser, S. et al. The meaning of net zero and how to get it right. Nat. Clim. Change **12**, 15–21 (2022).

44. OECD. The Climate Action Monitor 2022: Helping Countries Advance Towards Net Zero. (OECD, 2022). doi:10.1787/43730392-en.

45. Fuss, S. et al. Negative emissions—Part 2: Costs, potentials and side effects. Environ. Res. Lett. **13**, 063002 (2018).

46. UNFCCC Conference of the Parties. Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its third session, held in Glasgow from 31 October to 13 November 2021. Addendum. Part two: Action taken by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement at its third session (FCCC/PA/CMA/2021/10/Add.1).

47. Pathak, M. et al. Technical Summary. in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Shukla, P. et al.) (Cambridge University Press, 2022). doi:10.1017/9781009157926.002.

48. National Research Council. Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration. 18805 (National Academies Press, 2015). doi:10.17226/18805.

49. IEAGHG. Global Assessment of Direct Air Capture Costs (2021-05).

50. Goldberg, D. S., Lackner, K. S., Han, P., Slagle, A. L. & Wang, T. Co-Location of Air Capture, Subseafloor CO 2 Sequestration, and Energy Production on the Kerguelen Plateau. Environ. Sci. Technol. **47**, 7521–7529 (2013).

51. Koide, H. et al. Underground storage of carbon dioxide in depleted natural gas reservoirs and in useless aquifers. Eng. Geol. **34**, 175–179 (1993).

52. Hendriks, C. A. & Blok, K. Underground storage of carbon dioxide. Energy Convers. Manag. **34**, 949–957 (1993).

53. Pianta, S., Rinscheid, A. & Weber, E. U. Carbon Capture and Storage in the United States: Perceptions, preferences, and lessons for policy. Energy Policy **151**, 112149 (2021).

54. Krey, V., Luderer, G., Clarke, L. & Kriegler, E. Getting from here to there – energy technology transformation pathways in the EMF27 scenarios. Clim. Change **123**, 369–382 (2014).

55. Smith, P. et al. Biophysical and economic limits to negative CO2 emissions. Nat. Clim. Change **6**, 42–50 (2016).

56. Creutzig, F. et al. Bioenergy and climate change mitigation: an assessment. GCB Bioenergy **7**, 916–944 (2015).

57. Nabuurs, G.-J. et al. Agriculture, Forestry and Other Land Uses (AFOLU). in Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Shukla, P. et al.) 747–860 (Cambridge University Press, 2022).

58. Olsson, L. et al. Land Degradation. in Climate Change and Land: IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems (eds. Shukla, P. et al.) (Cambridge University Press, 2019). doi:10.1017/9781009157988.

59. 4 per 1000. Why the '4 per 1000' Initiative: Soils for Food Security and Climate. The international '4 per 1000' Initiative https://4p1000.org/discover/?lang=en.

60. 4 per 1000. Strategic Plan. 2nd version. (2022).

61. UNCCD. Land Degradation Neutrality. UNCCD https://www.unccd.int/land-and-life/land-degradation-neutrality/overview (2023).

62. Republic of Kazakhstan. Kazakhstan Final Report on the Target Setting Program LDN. 40 https://www.unccd.int/sites/default/files/ldn_targets/2018-11/Kazakhstan%20LDN%20TSP%20Country%20Report.pdf (2018).

63. Lal, R. Influence of Soil Erosion on Carbon Dynamics in the World. in Soil Erosion and Carbon Dynamics (eds. Roose, E. J., Lal, R., Feller, C., Barthes, B. & Stewart, B.) 23–35 (CRC Press, 2005).

64. Chen, J. et al. Social-Ecological Systems Across the Asian Drylands Belt (ADB). in Landscape Dynamics of Drylands across Greater Central Asia: People, Societies and Ecosystems. Landscape Series (eds. Gutman, G., Chen, J., Henebry, G. & Kappas, M.) vol. 17 191–225 (Springer, 2020).

65. UNCCD. Article 1. Use of terms. UNCCD https://www.unccd.int/article-1-use-terms.

66. Vorobiev G, Anuchin N. Forest encyclopaedia. Soviet Encyclopaedia (1985).

67. European Commission. Joint Research Centre. World atlas of desertification: rethinking land degradation and sustainable land management. (Publications Office, 2018).

68. Ellsworth, D. S. et al. Convergence in phosphorus constraints to photosynthesis in forests around the world. Nat. Commun. **13**, 5005 (2022).

69. 69. Tribunskaya V, Kostina N, Sherbakova L, Astafiev N. Agro-economic effectiveness of

70. shelterbelts. Lesnaya Promyshlennost (1974).

71. Qi, J., Xin, X., John, R., Groisman, P. & Chen, J. Understanding livestock production and sustainability of grassland ecosystems in the Asian Dryland Belt. Ecol. Process. **6**, 22 (2017).

72. Robinson, S., Milner-Gulland, E. J. & Alimaev, I. Rangeland degradation in Kazakhstan during the Soviet era: re-examining the evidence. J. Arid Environ. **53**, 419–439 (2003).

73. Repetto, R. Renewable resources and population growth: Past experiences and future prospects. Popul. Environ. **10**, 221–236 (1989).

74. Reynolds, J. F. et al. Global Desertification: Building a Science for Dryland Development. Science **316**, 847–851 (2007).

75. Mirzabaev, A., Ahmed, M., Werner, J., Pender, J. & Louhaichi, M. Rangelands of Central Asia: challenges and opportunities. J. Arid Land **8**, 93–108 (2016).

76. Pueppke, S., Nurtazin, S., Graham, N. & Qi, J. Central Asia's Ili River Ecosystem as a Wicked Problem: Unraveling Complex Interrelationships at the Interface of Water, Energy, and Food. Water **10**, 541 (2018).

77. Micklin, P. The Aral Sea Disaster. Annu. Rev. Earth Planet. Sci. **35**, 47–72 (2007).

78. Qadir, M. et al. Salt-induced land and water degradation in the Aral Sea basin: A challenge to sustainable agriculture in Central Asia. Nat. Resour. Forum **33**, 134–149 (2009).

79. Chub, V., Executive Committee of the International Fund for Saving the Aral Sea, World Bank, & Main Administration for Hydrometeorology of Uzbekistan. Regional problems of estimating the influence of aerosols (of anthropogenic and natural occurrence) on the climatic characteristics of the Central Asiatic region. in Materials for the Regional Scientific Seminar Aeolian Transport of Salt in the Aral Sea Basin 3–4 (1998).

80. Starodubtsev, V. M. & Truskavetskiy, S. R. Desertification processes in the Ili River delta under anthropogenic pressure. Water Resour. **38**, 253–256 (2011).

81. Dostay, Z., Alimkulov, S., Tursunova, A. & Myrzakhmetov, A. Modern hydrological status of the estuary of Ili River. Appl. Water Sci. **2**, 227–233 (2012).

82. Petr, T. & Mitrofanov, V. P. The impact on fish stocks of river regulation in Central Asia and Kazakhstan. Lakes Reserv. Sci. Policy Manag. Sustain. Use **3**, 143–164 (1998).

83. Micklin, P. The Water Management Crisis in Soviet Central Asia. (1991).

84. Moseley, G. A Sino-Soviet Cultural Frontier: The Ili Kazakh Autonomous Chou. (Harvard University Asia Center, 1966). doi:10.2307/j.ctt1tg5n34

84. Qushimov, J., Ganiev, I., Rustamova, I., Haitov, B. & Islam, K. Land degradation by agricultural activities in Central Asia. in Climate Change and Terrestrial Carbon Sequestration in Central Asia (eds. Lal, R., Suleimenov, M., Stewart, B., Hansen, D. & Doraiswamy, P.) 137–146 (2007).

85. The United Nations world water development report 2014. (UNESCO, 2014).

86. Abdullaev, I. & Rakhmatullaev, S. Setting up the agenda for water reforms in Central Asia: Does the nexus approach help? Environ. Earth Sci. **75**, 870, s12665-016-5409–8 (2016).

87. Timirkhanov, S. et al. Fisheries and aquaculture in the Republic of Kazakhstan: a review. (2010).

88. Lioubimtseva, E. & Henebry, G. M. Climate and environmental change in arid Central Asia: Impacts, vulnerability, and adaptations. J. Arid Environ. **73**, 963–977 (2009).

89. Goudie, A. Deserts in a warmer world. in Environmental Change in Drylands: Biogeographical and Geomorphological Perspectives (eds. Millington, A. & Pye, K.) 1–29 (1994).

90. Lioubimtseva, E. & Cole, R. Uncertainties of Climate Change in Arid Environments of Central Asia. Rev. Fish. Sci. **14**, 29–49 (2006).

91. Melillo, J. M. et al. Global climate change and terrestrial net primary production. Nature **363**, 234–240 (1993).

92. Lahiri-Dutt, K. & Dondov, H. Informal mining in Mongolia: livelihood change and continuity in the rangelands. Local Environ. **22**, 126–139 (2017).

93. World Bank Group. China Country Climate and Development Report. (World Bank, 2022). doi:10.1596/38136.

94. Sternberg, T., Bolay, M., Haller, T. & Niederberger, T. The 'open cut' in drylands: Challenges of artisanal mining and pastoralism encountering industrial mining, development, and resource grabbing. in Drylands Facing Change 93–111 (Routledge, 2022). doi:10.4324/9781003174486-8.

95. World Bank Group. Kazakhstan: Country Climate and Development Report. Background Note 2: Kazakhstan's opportunities in green products and value chains. (2022).

96. IPCC. Summary for Policymakers. in Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems (eds. Shukla, P. et al.) (2019).

97. National Statistics Bureau (Kazakhstan). Gross Production of Agricultural Crops in the Republic of Kazakhstan. https://stat.gov.kz/ru/industries/business-statistics/stat-forrest-village-hunt-fish/publications/5099 (2022).

98. Steduto, P., Hsiao, T., Fereres, E. & Raes, D. Crop yield response to water. (FAO, 2012).

99. Akhmadiyeva, Z. Climate Change and Possible Changes in the Water Regime of Crops in Northern Kazakhstan. in Environmental Problems of Central Asia and Their Economic, Social and Security Impacts (eds. Qi, J. & Evered, K.) (2008).

100. Lal, R. Restoring Soil Quality to Mitigate Soil Degradation. Sustainability **7**, 5875–5895 (2015).

101. UNCCD. Sustainable Land Management for Climate and People. catalogue.unccd.int/SER_SPIPB_3_ENG_WEB.pdf (2017).

102. Ahmed, M. et al. Impact of Climate Change on Dryland Agricultural Systems: A Review of Current Status, Potentials, and Further Work Need. Int. J. Plant Prod. **16**, 341–363 (2022).

103. European Land Owner's Organization. Carbon Farming: the landowners' perspective. (2021)

104. Vienne, A. et al. Enhanced Weathering Using Basalt Rock Powder: Carbon Sequestration, Co-benefits and Risks in a Mesocosm Study With Solanum tuberosum. Front. Clim. **4**, 869456 (2022).

105. Smith, P. et al. Agriculture, Forestry and Other Land Use (AFOLU). in Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds. Edenhofer, O. et al.) (2014).

106. IPCC. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. vol. 4 'Agriculture, Forestry and Other Land Use.'.

107. Santos, N. Accelerating Adoption of Climate Technologies in the Agrifood Sector (Istanbul, 12 April 2019). http://evf.gov.tr/content/files/Konusmaci_Sunumlari/yabanci-konusmacilar/Acc-Adoption-Climate-Techs-Agrifood_Santos_Istanbul.pdf.

108. Polo, M. d. M., Santos, N. & Syzdykov, Y. Adoption of climate technologies in the agrifood system: investment opportunities in Kazakhstan. (FAO, 2022).

109. Sun, W. et al. Climate drives global soil carbon sequestration and crop yield changes under conservation agriculture. Glob. Change Biol. **26**, 3325–3335 (2020).

110. FAO. Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan. (2012).

111. Valkama, E., Acutis, M., Kunypiyaeva, G., Zhapaev, R. & Karabayev, M. Modelling of Soil Organic Carbon Dynamics in Kazakhstan. in Proceedings of the 10th International Soil Science Congress on Environment and Soil Resources Conservation (eds. Saparov, A. & Kizilkaya, R.) 155–158 (2018).

112. Valkama, E. et al. Can conservation agriculture increase soil carbon sequestration? A modelling approach. Geoderma **369**, 114298 (2020).

113. Mikhailova, E. A., Bryant, R. B., Vassenev, I. I., Schwager, S. J. & Post, C. J. Cultivation Effects on Soil Carbon and Nitrogen Contents at Depth in the Russian Chernozem. Soil Sci. Soc. Am. J. **64**, 738–745 (2000).

114. Beniston, J. W., DuPont, S. T., Glover, J. D., Lal, R. & Dungait, J. A. J. Soil organic carbon dynamics 75 years after land-use change in perennial grassland and annual wheat agricultural systems. Biogeochemistry **120**, 37–49 (2014).

115. Perez-Quezada, J. F., Saliendra, N. Z., Akshalov, K., Johnson, D. A. & Laca, E. A. Land Use Influences Carbon Fluxes in Northern Kazakhstan. Rangel. Ecol. Manag. **63**, 82–93 (2010).

116. Paroda, R. Addressing the challenges for sustainable agriculture in Central Asia. in Climate Change and Terrestrial Carbon Sequestration in Central Asia (eds. Lal, R., Suleimenov, M., Stewart, B. A., Hansen, D. O. & Doraiswamy, P.) 109–126 (Taylor & Francis, 2007). doi:10.1201/9780203932698-17.

117. Feliciano, D., Ledo, A., Hillier, J. & Nayak, D. R. Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions? Agric. Ecosyst. Environ. **254**, 117–129 (2018).

118. USDA. Alley Cropping: An Agroforestry Practice. Agroforestry Notes (2017).

119. Singh, R. P., Saharan, N. & Ong, C. K. Above and below ground interactions in alley-cropping in semi-arid India. Agrofor. Syst. **9**, 259–274 (1989).

120. Thevs, N. & Aliev, K. Agro-economy of tree wind break systems in Kyrgyzstan, Central Asia. Agrofor. Syst. **97**, 319–334 (2023).

121. Thevs, N., Aliev, K. & Lleshi, R. Water productivity of tree wind break agroforestry systems in irrigated agriculture – An example from Ferghana Valley, Kyrgyzstan. Trees For. People **4**, 100085 (2021).

122. USDA. Conservation Practice Standard: Critical Area Planting. https://www.nrcs.usda.gov/sites/default/files/2022-09/Critical_Area_Planting_342_CPS.pdf (2016).

123. USDA. Can windbreaks benefit your soil health management system? Working Trees Info (2017).

124. Kantola, I. B. et al. Improved net carbon budgets in the US Midwest through direct measured impacts of enhanced weathering. Glob. Change Biol. gcb.16903 (2023) doi:10.1111/gcb.16903.

125. WOCAT. SLM Database (2023a). wocat.net https://qcat.wocat.net/en/wocat/.

126. WOCAT. Kazakhstan experts knowledge tool (2023b). https://wocatapps.users.earthengine.app/view/kazakhstan-experts.

127. WOCAT & Carbon Benefits Project (2023). Carbon Benefits Project: About. https://www.carbonbenefitsproject.org/.

128. The GEF Small Grants Programme. Promoting value chains for CSA groundnut in Binh Dinh, Phu Yen and Quang Tri provinces: Project detail. https://sgp.undp.org/spacial-itemid-projects-landing-page/spacial-itemid-project-search-results/spacial-itemid-project-detailpage.html?view=projectdetail&id=14154.

129. European Parliament. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (2018).

130. IRENA. Advanced biofuels. What holds them back? (2019).

131. IRENA. Biomass Co-firing. Technology brief. (2013).

132. Proskurina, S., Heinimö, J., Schipfer, F. & Vakkilainen, E. Biomass for industrial applications: The role of torrefaction. Renew. Energy **111**, 265–274 (2017).

133. Wild, M. & Calderón, C. Torrefied Biomass and Where Is the Sector Currently Standing in Terms of Research, Technology Development, and Implementation. Front. Energy Res. **9**, 678492 (2021).

134. Ryłko-Polak, I., Komala, W. & Białowiec, A. The Reuse of Biomass and Industrial Waste in Biocomposite Construction Materials for Decreasing Natural Resource Use and Mitigating the Environmental Impact of the Construction Industry: A Review. Materials **15**, 4078 (2022).

135. Møller, A. H. et al. Biorefinery of Green Biomass-How to Extract and Evaluate High Quality Leaf Protein for Food? J. Agric. Food Chem. **69**, 14341–14357 (2021).

136. Huang, K. et al. Greenhouse Gas Emission Mitigation Potential of Chemicals Produced from Biomass. ACS Sustain. Chem. Eng. **9**, 14480–14487 (2021).

137. UNFCCC. What is the Kyoto Protocol? | UNFCCC. https://unfccc.int/kyoto_protocol.

138. UNFCCC. Kyoto Protocol Signed. https://education.nationalgeographic.org/resource/kyoto-protocol-signed.

139. Wellner, K., Glock, D., Runge, P., Tschach, I. & Ruf, P. Analysis and Assessment of Market Structure, Trading Activities and Further Developments in the EU ETS. (2014)

140. Introducing the Carbon Market Age. https://www.msci.com/www/blog-posts/introducing-the-carbon-market/03227158119.

141. European Commission. EU Emissions Trading System (EU ETS). https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en.

142. Statista. Largest ETS markets by coverage 2022. Statista https://www.statista.com/statistics/1315109/largest-ets-markets-by-coverage/.

143. ICAP. ICAP ETS Map (2023).

144. ICAP. ICAP Brief 6: Allocation of allowances (2021).

145. European Commission. COMMISSION DELEGATED REGULATION (EU) 2019/331. (2018).

146. Department for Business, Energy, & Industrial Strategy & Department for Energy Security & Net Zero. Participating in the UK ETS. GOV.UK https://www.gov.uk/government/publications/participating-in-the-uk-ets/participating-in-the-uk-ets (2023).

147. Kris, N. Compliance Carbon Markets: Consultation Report. (2022).

148. ICAP. Kazakhstan Emissions Trading System | International Carbon Action Partnership. https://icapcarbonaction.com/en/ets/kazakhstan-emissions-trading-system (2018).

149. Republic of Kazakhstan. Environmental Code of the Republic of Kazakhstan (2021).

150. Kris, N. Voluntary Carbon Markets: Discussion Paper. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.iosco.org/library/pubdocs/pdf/IOSCOPD718.pdf (2022).

151. La Hoz Theuer, S. et al. ICAP: Offset Use Across ETS. (2023).

152. Paia Consulting. Carbon Offsets and Credits, Explained. Paia Consulting https://paiaconsulting.com.sg/carbon-offsets-and-credits-explained/ (2021).

153. Porsborg-Smith, A., Nielsen, J., Owolabi, B. & Clayton, C. The Voluntary Carbon Market Is Thriving. Energy Transition https://www.bcg.com/publications/2023/why-the-voluntary-carbon-market-is-thriving (2023).

154. Bloomberg NEF. The Untapped Power of Carbon Markets in Five Charts. BloombergNEF https://about.bnef.com/blog/the-untapped-power-of-carbon-markets-in-five-charts/ (2022).

155. Blaufelder, C., Katz, J., Levy, C., Pinner, D. & Weterings, J. How the voluntary carbon market can help address climate change | McKinsey. Our Insights https://www.mckinsey.com/capabilities/sustainability/our-insights/how-the-voluntary-carbon-market-can-help-address-climate-change (2020).

156. Greenfield, P. Revealed: more than 90% of rainforest carbon offsets by biggest certifier are worthless, analysis shows. The Guardian (2023).

157. Carton, W., Asiyanbi, A., Beck, S., Buck, H. J. & Lund, J. F. Negative emissions and the long history of carbon removal. WIREs Clim. Change **11**, e671 (2020).

158. Blaufelder, C., Levy, C., Mannion, P. & Pinner, D. Carbon credits: Scaling voluntary markets | McKinsey. https://www.mckinsey.com/capabilities/sustainability/our-insights/a-blueprint-for-scaling-voluntary-carbon-markets-to-meet-the-climate-challenge (2021).

159. Forest Trends' Ecosystem Marketplace. The Art of Integrity: State of Voluntary Carbon Markets, Q3 Insights Briefing. (2022).

160. Carbon Removal Alliance. Carbon Removal Alliance Homepage. Carbon Removal Alliance https://www.carbonremovalalliance.org.

161. Center For Climate And Energy Solutions. Carbon Tax Basics. https://www.c2es.org/content/carbon-tax-basics/.

162. Parry, I. W. H., Black, S. & Zhunussova, K. Carbon Taxes or Emissions Trading Systems?: Instrument Choice and Design. A001 https://www.elibrary.imf.org/view/journals/066/2022/006/article-A001-en.xml (2022).

163. ICAP. Emissions Trading and Carbon Tax: Two Instruments, One Goal. (2021).

164. Smith, S. M. et al. The State of Carbon Dioxide Removal - 1st Edition. http://dx.doi.org/10.17605/OSF.IO/W3B4Z (2023) doi:10.17605/OSF.IO/W3B4Z.

165. Galik, C. S., Baker, J. S., Daigneault, A. & Latta, G. Crediting temporary forest carbon: Retrospective and empirical perspectives on accounting options. Front. For. Glob. Change **5**, (2022).

166. Richards, K. R. The time value of carbon in bottom-up studies. Crit. Rev. Environ. Sci. Technol. **27**, 279–292 (1997).

167. Chay, F. et al. Unpacking ton-year accounting – CarbonPlan. Carbonplan.org https://carbonplan.org/research/ton-year-explainer (2022).

168. Nordhaus, W. Life After Kyoto: Alternative Approaches to Global Warming. NBER Work. Pap. (2005).

169. Boyce, J. K. Carbon Pricing: Effectiveness and Equity. Ecol. Econ. **150**, 52–61 (2018).

170. UNFCCC. About Carbon Pricing | UNFCCC. unfccc.int https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca/about-carbon-pricing#Which-types-of-carbon-pricing-exist?-.

171. European Commission. Questions and Answers - Emissions Trading – Putting a Price on carbon. European Commission - European Commission https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542 (2021).

172. Jonsson, S., Ydstedt, A. & Asen, E. Looking Back on 30 Years of Carbon Taxes in Sweden. Research https://taxfoundation.org/research/all/eu/sweden-carbon-tax-revenue-greenhouse-gas-emissions/ (2020).

173. Aldy, J. E. & Stavins, R. N. The Promise and Problems of Pricing Carbon: Theory and Experience. J. Environ. Dev. **21**, 152–180 (2012).

174. Tagliapietra, S. & Demertzis, M. Carbon price floors: an addition to the European Green Deal arsenal. Bruegel | The Brussels-based economic think tank https://www.bruegel.org/blog-post/carbon-price-floors-addition-european-green-deal-arsenal (2023).

175. HMRC. VATSC06583 - Consideration: Payments that are not consideration: Payments in specific sectors: Carbon offsetting: Voluntary non-compliance market - HMRC internal manual - GOV.UK. (2016).

176. OECD. Effective Carbon Rates 2021: Pricing Carbon Emissions through Taxes and Emissions Tradin. (OECD Publishing, 2021). doi:https://doi.org/https://doi.org/10.1787/0e8e24f5-en.

177. World Bank. Kazakhstan - Country Climate and Development Report : Executive Summary. World Bank https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099420411012224422/P177369030d1f80bb091040734a3ba38bdf.

178. IMF. Republic of Kazakhstan: Selected Issues. IMF Staff Ctry. Rep. **2022**, (2022).

179. On The Way to a Global Carbon Market: Linking Emissions Trading Systems. https://icapcarbonaction.com/en/linking.

180. Ruggiero, A. A brief explanation of the Carbon Border Adjustment Mechanism (CBAM). https://carbonmarketwatch.org/2021/12/16/a-brief-explanation-of-the-cbam-proposal/ (2022).

181. Ryszka, K. & Poolen, D. Can voluntary carbon markets change the game for climate change? Research https://www.rabobank.com/knowledge/d011295824-can-voluntary-carbon-markets-change-the-game-for-climate-change (2021).

182. CARBON PRICING: What is a carbon credit worth? | The Gold Standard. https://www.goldstandard.org/blog-item/carbon-pricing-what-carbon-credit-worth (2023).

183. Roe, S. et al. Land-based measures to mitigate climate change: Potential and feasibility by country. Glob. Change Biol. **27**, 6025–6058 (2021).

184. Golub, A. et al. Climate alpha and the global capital market. Fondazione Eni Enrico Mattei FEEM 39 (2022).

185. The greenhouse gas protocol: a corporate accounting and reporting standard. (World Business Council for Sustainable Development ; World Resources Institute, 2004).

186. Smith, B. Microsoft will be carbon negative by 2030. https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/ (2020).

187. Joppa, L. et al. Microsoft's million-tonne CO2-removal purchase — lessons for net zero. Nature **597**, 629–632 (2021).

188. Ministry of Environment, Government of Japan. Japan and Republic of Kazakhstan Sign the Memorandum of Cooperation for Establishing the JCM. Press & Public Relations https://www.env.go.jp/en/press/press_02091.html (2023).

189. Salmukhanbetova, Zh. K., Imanalinova, A. A., Dimeyeva, L. A. & Zverev, N. E. State of Saxaul Plantations in the Kazakhstan's Part of the Aral Sea Area. Cent. Asian J. Water Res. **7**, 127–158 (2021).

190. Demeyer, A. et al. Policy recommendations on how to incentivise carbon farming. 40 https://northsearegion.eu/carbon-farming/news/policy-recommendations-on-how-to-incentivise-carbon-farming/ (2021).

191. Akhmadiyeva, Z. & Herzfeld, T. The Reality of Land Rights in Kazakhstan and Uzbekistan. https://www.iamo.de/fileadmin/user_upload/iamo2021_en_c1.pdf (2021).

192. Official Information Source of the Prime Minister of the Republic of Kazakhstan. Development of agricultural sector for 2021 and plans for coming period - Official Information Source of the Prime Minister of the Republic of Kazakhstan. https://primeminister.kz/en/news/reviews/itogi-razvitiya-sfery-selskogo-hozyaystva-za-2021-god-i-plany-na-predstoyashchiy-period-22422 (2022).

193. USA International Trade Administration. Kazakhstan Country Commercial Guide - Agricultural Sector. https://www.trade.gov/country-commercial-guides/kazakhstan-agricultural-sector (2022).

194. FCPF. Validation and Verification Guidelines. (2021).

195. TREES. ART Architecture for REDD+ Transactions https://www.artredd.org/trees/.

196. ART. TREES: The REDD+ Environmental Excellence Standard. https://www.artredd.org (2021).

197. Jurisdictional & Nested Redd+ Framework. Verra https://verra.org/programs/jurisdictional-nested-redd-framework/.

198. CTF Standard. California Tropical Forest Standard. California Air Resources Board https://ww2.arb.ca.gov/our-work/programs/california-tropical-forest-standard.

199. Kurganova, I., Lopes de Gerenyu, V. & Kuzyakov, Y. Large-scale carbon sequestration in post-agrogenic ecosystems in Russia and Kazakhstan. CATENA **133**, 461–466 (2015).

200. Smith, P. et al. How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Glob. Change Biol. **26**, 219–241 (2020).

201. Bey, N. et al. Certifications of Carbon Removal: Part 1: Synoptic review of carbon removal solutions. 126 (2021).

202. Ebert, C. et al. U.S. Soil Enrichment Protocol. 161 https://www.climateactionreserve.org/how/protocols/ncs/soil-enrichment/ (2021).

203. Compensate. What is double counting and why is it such a big deal? - Compensate. compensate.com https://compensate.com/articles/what-is-double-counting-and-why-is-it-such-a-big-deal (2021).

204. MacDonald, A. Guide to Carbon Credit Buffer Pools. www.sylvera.com https://www.sylvera.com/blog/carbon-credit-buffer-pools (2022).

205. Australian Government Clean Energy Regulator. Emissions Reduction Fund: Risk of reversal buffer. cleanenergyregulator.gov.au https://www.cleanenergyregulator.gov.au/ERF/Choosing-a-project-type/Opportunities-for-the-land-sector/Risk-of-reversal-buffer (2018).

206. World Bank & Duarte, M. Climate Explainer: Concessional Finance. Feature Story https://www.worldbank.org/en/news/feature/2021/09/16/what-you-need-to-know-about-concessional-finance-for-climate-action (2021).

207. FABLE et al. Prosperous Land, Prosperous People: Scaling finance for Nature-based Solutions in Kenya. https://www.foodandlandusecoalition.org/wp-content/uploads/2022/11/FOLU-Financing-NBS-Report_Kenya_091122_Prosperous_Land_Prosperous_People.pdf (2022).

208. ICMA. Green Bond Principles » ICMA. icmagroup.org https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/green-bond-principles-gbp/ (2021).

209. Climate Bonds Initiative. Certification under the Climate Bonds Standard. Climate Bonds Initiative https://www.climatebonds.net/certification (2018).

210. The Nature Conservancy. Who We Are | The Nature Conservancy. www.nature.org https://www.nature.org/en-us/about-us/who-we-are/.

211. Global Landscape Forum. Publication: Sustainable Land Bonds: How governments can finance climate commitments and strengthen rural economies. Global Landscapes Forum https://www.globallandscapesforum.org/publication/sustainable-land-bonds-how-governments-can-finance-climate-commitments-and-strengthen-rural-economies/ (2018).

212. Golub, A., Herrera, D., Leslie, G., Pietracci, B. & Lubowski, R. A real options framework for reducing emissions from deforestation: Reconciling short-term incentives with long-term benefits from conservation and agricultural intensification. Ecosyst. Serv. **49**, (2021).

213. Golub, A. A. et al. Escaping the climate policy uncertainty trap: options contracts for REDD+. Clim. Policy **18**, 1227–1234 (2018).

214. Seidle, T. Land Restoration and Carbon Removal Partnership. Earthbanc https://earthbanc.io/2023/02/01/earthbanc-announces-partnership-with-the-unccd-to-finance-land-restoration-and-carbon-removal/ (2023).

215. EarthBanc. Tree Planting - Meghalaya. earthbanc.io https://whitelabel-checkout.earthbanc.io/detail?ticker=TRME (2023).

216. Willard, M. Regional Carbon Farming? An Italian Example | The Case for Regional Carbon Farming: An Italian Example. Agricultural and Rural Convention https://www.arc2020.eu/can-carbon-farming-be-managed-on-a-regional-level-and-how-private-agencies-might-ease-the-transition/ (2023).

217. Land Degradation Neutrality Fund. UNCCD https://www.unccd.int/land-and-life/land-degradation-neutrality/impact-investment-fund-land-degradation-neutrality.

218. 218. Mirova. Land Degradation Neutrality Fund (LDN): 2022 Impact Report. Mirova https://www.mirova.com/en/ideas/land-degradation-neutrality-fund-ldn-2022-impact-report (2023).

219. Gaviano, A. & Alvaro, A. The seven key elements of an Environmental and Social Management System. Sostenibilidad https://blogs.iadb.org/sostenibilidad/en/espf-environmental-and-social-management-system/ (2022).

220. European Investment Bank. Land Degradation Neutrality Fund. eib.org https://www.eib.org/en/products/equity/funds/land-degradation-neutrality-fund (2023).

221. UNCCD. Voluntary LDN targets. unccd.int https://www.unccd.int/our-work/country-profiles/voluntary-ldn-targets (2023).

222. European Commission. Communication From the Commission to The European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. (2011).

223. Ürge-Vorsatz, D., Herrero, S. T., Dubash, N. K. & Lecocq, F. Measuring the Co-Benefits of Climate Change Mitigation. Annu. Rev. Environ. Resour. **39**, 549–582 (2014).

224. Gore, C. & Robinson, P. 136137Local Government Response to Climate Change: Our Last, Best Hope? in Changing Climates in North American Politics: Institutions, Policymaking, and Multilevel Governance (eds. Selin, H. & VanDeveer, S. D.) 0 (The MIT Press, 2009). doi:10.7551/mitpress/9780262012997.003.0007.

225. 225. Kostka, G. & Hobbs, W. Local Energy Efficiency Policy Implementation in China: Bridging the Gap between National Priorities and Local Interests. China Q. **211**, 765–785 (2012).

226. Teng, F. & Gu, A. Climate change: national and local policy opportunities in China. Environ. Sci. **4**, 183–194 (2007).

227. Ye Qi, Li Ma, Huanbo Zhang, & Huimin Li. Translating a Global Issue Into Local Priority: China's Local Government Response to Climate Change. J. Environ. Dev. **17**, 379–400 (2008).

228. Atteridge, A., Shrivastava, M. K., Pahuja, N. & Upadhyay, H. Climate Policy in India: What Shapes International, National and State Policy? AMBIO **41**, 68–77 (2012).

229. Hochstetler, K. & Viola, E. Brazil and the politics of climate change: beyond the global commons. Environ. Polit. **21**, 753–771 (2012).

230. United Nations General Assembly. Resolution adopted by the General Assembly on 25 September 2015. in (2015).

231. UNEP. Sustainable development goals | World Environment Situation Room Data, Information and Knowledge on the Environment by UNEP. World Environment Situation Room Data, Information and Knowledge on the Environment https://wesr.unep.org/article/sustainable-development-goals-0.

232. Sustainable Development Report 2023. https://dashboards.sdgindex.org/.

233. UNEP. The Future We Want. in Agenda item 10 Outcome of the Conference (United Nations, 2012).

234. Sims, N. C. et al. Good Practice Guidance SDG Indicator 15.3.1 Proportion of land that is degraded over total land area. (2021).

235. European Commission. SDG Mapper Intro | KnowSDGs. jrc.ec.europa.eu https://knowsdgs.jrc.ec.europa.eu/sdgmapper?check_logged_in=1 (2023).

236. Tang, K., Kragt, M., Hailu, A. & Ma, C. Carbon farming economics: What have we learned? J. Environ. Manage. **172,** 49–57 (2016).

237. Amin, M. N., Lobry de Bruyn, L., Hossain, M. S., Lawson, A. & Wilson, B. The Social-Ecological System of Farmers' Current Soil Carbon Management in Australian Grazing Lands. Environ. Manage. **72**, 294–308 (2023).

238. Amin, M. N., Hossain, M. S., Lobry de Bruyn, L. & Wilson, B. A systematic review of soil carbon management in Australia and the need for a social-ecological systems framework. Sci. Total Environ. **719**, 135182 (2020).

239. Hamidov, A. et al. Impacts of climate change adaptation options on soil functions: A review of European case-studies. Land Degrad. Dev. **29**, 2378–2389 (2018).

240. Miller, K. A., Snyder, S. A. & Kilgore, M. A. An assessment of forest landowner interest in selling forest carbon credits in the Lake States, USA. For. Policy Econ. **25**, 113–122 (2012).

241. Issanova, G., Mamirova, K. & Semenov, O. Dust storms in Kazakhstan. in (2014).

242. Akramkhanov, A. et al. The Value of Landscape Restoration in Uzbekistan to Reduce Sand and Dust Storms from the Aral Seabed. https://openknowledge.worldbank.org/entities/publication/ae8e90f5-6e66-5c12-9695-364de8003b14 (2021).

243. Official Information Source of the Prime Minister of the Republic of Kazakhstan. Government considers issues of using water resources - Official Information Source of the Prime Minister of the Republic of Kazakhstan. primeminister.kz https://primeminister.kz/en/news/pravitelstvo-rassmotrelo-voprosy-ispolzovaniya-vodnyh-resursov-22112056 (2020).

244. UNDP. The climate change impact on water resources in Kazakhstan | United Nations Development Programme. UNDP Kazakhstan Stories https://www.undp.org/kazakhstan/stories/climate-change-impact-water-resources-kazakhstan (2021).

245. Toensmeier, E. The carbon farming solution: a global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security. (Chelsea Green Publishing, 2016).

246. Tse, P-K. China's Rare-Earth Industry: U.S. Geological Survey Open-File Report (US Geological Survey 2011). https://pubs.usgs.gov/of/2011/1042/of2011-1042.pdf.

247. Susa NI. Agroforestry melioration. Governmental Publishing House for Agriculture (1959).

248. Tribunskaya V, Kostina N, Sherbakova L, Astafiev N. Agro-economic effectiveness of shelterbelts. Lesnaya Promyshlennost (1974).

249. Roe S et al. Land-based measures to mitigate climate change: Potential and feasibility by country. Global Change Biology 27, 6025-6058 (2021). doi.org/10.1111/gcb.15873.