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MASTER THESIS

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APPLICATION FOR THE AWARDING OF A DEGREE

Second Cycle Degree Course in Second cycle degree/Two years Master in ECONOMICS, FINANCE AND INTERNATIONAL INTEGRATION

STUDENT ID NR 512154

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of the Università degli Studi di PAVIA

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Enrolled in this University

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To be ADMITTED to the final exam for the awarding of a degree in the summer session

of the academic year 2022/2023 and issue of the the original degree title

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TITLE OF FINAL THESIS: Climate change and agriculture in Central Asia: adaptation and mitigation through the agri-food system

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Climate change and agriculture in Central Asia: adaptation and mitigation through the agri-food system.

Abstract:

Agriculture takes an important role in the social and economical activities of Central Asian countries, contributing up to 24% of the GDP and providing approximately 50% of jobs in rural areas. However, the agricultural sector is currently facing crucial challenges under pressure of climate change and heat stress. Rising temperatures and shifting precipitation patterns are expected to result in reduced crop yields, increased water stress, and more frequent extreme weather events, such as droughts and floods. Additionally, agriculture is a substantial contributor to greenhouse gas (GHG) emissions, accounting for 13% of global emissions, particularly in the form of methane (CH4) and nitrous oxide. Thesis aims to comprehensively understand the causes and consequences of climate change on agriculture while proposing a range of adaptation and mitigation strategies specifically for the livestock sector. The study employs a mixed research methodology, utilizing the FAO's online platform GLEAM-i to estimate emissions from the livestock sector in the region. Through this research, it is anticipated that a deeper understanding of the complex relationship between climate change and agriculture will be achieved. Moreover, the findings will contribute to the development of practical measures that can be implemented to enhance the resilience of the livestock sector and reduce its environmental footprint in Central Asia.

Key words: Heat stress, livestock, Central Asian, GLEAM-i, adoption, mitigation

LIST OF FIGURES

LIST OF ABBREVIATIONS

CH4 Methane

CO2 Carbon dioxide

CO2 kgCO2-eq Carbon dioxide kilogram equivalent

COP26 26th Conference of Parties

EBRD The European Bank for Reconstruction and Development

EU European Union

FAO The Food and Agriculture Organization of the United Nations

GDP Gross domestic product

GHG Greenhouse Gas

GLEAM-i The Global Livestock Environmental Assessment Model - interactive

NO2 Nitrogen Dioxide

IFAD The International Fund for Agricultural Development

IPCC - Intergovernmental Panel on Climate Change

IPCC Intergovernmental Panel on Climate Change

UNDP The United Nations Development Programme

UNFCCC The United Nations Framework Convention on Climate Change

Introduction

Climate change refers to one of the global problems of several decades, which in the long term effects changes in temperature, precipitation, wind patterns, and other climatic indicators. Since the mid-20th century, greenhouse gas emissions, including carbon dioxide, methane, and nitrous oxide, have been the main driver of climate change. More than half of the increase in CO2 concentration in the atmosphere since 1970 has been caused by human activity, especially the burning of fossil fuels, which has led to an increase in the average surface temperature of the earth by about 1°C since 1900. The further extent and timing of these changes will depend on many factors, and long-term climate change over many decades will depend mainly on the total amount of CO2 and other greenhouse gases emitted as a result of human activities.[1]

"The Global Risks Report for 2023", prepared by the World Economic, submitted the estimated top 10 short, as well long-term risks that highlight the most significant challenges confronting the world in the coming 2-10 years. Where 5-6 environmental problems were included both in the short and long term, in the top 3 long-term risks of warning associated with the failure of measures to mitigate the consequences of climate change and adaptation to them, as well as a risk with natural disasters and extreme weather events.[2]

In 2021, the Intergovernmental Panel on Climate Change (IPCC) working group proclaimed a red code warning about the climate change crisis, that the internationally acquiesced threshold may soon overcome 1.5 degrees Celsius, which puts billions of people at immediate risk.[3]

The United Nations Framework Convention on Climate Change (UNFCCC), which aims to reduce greenhouse gas emissions and combat climate change, signed the Glasgow Climate Pact at the yearly 26th Conference of Parties (COP26). Pact is a compromise that takes important steps, but global greenhouse gas emissions nevertheless need to be reduced further, and support for vulnerable countries affected by climate change falls short.

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[1] National Academy of Sciences, Royal society. "Climate Change Evidence & Causes". 2020

[2] "Global Risks Report 2023 | World Economic Forum.".. World Economic Forum. 2023. https://www.weforum.org/reports/global-risks-report-2023/digest.

[3] "Secretary-General's Statement on the IPCC Working Group 1 Report on the Physical Science Basis of the Sixth Assessment | United Nations Secretary-General.". 2021. https://www.un.org/sg/en/content/secretary-generals-statement-the-ipcc-working-group-1-report-the-physical-science-basis-of-the-sixth-assessment.

An essential outcome of COP26 for agriculture was that 137 countries committed to halt and reverse forest loss and land degradation by 2030, with $12bn in public and $7.2bn in private funding. Overall 30 financial institutions are involved in elimination investment around $8.7 trillion to reforestation activities around the world. In addition, 103 countries, including 15 major emitters, signed up to the Global Methane Pledge, which aims to limit methane emissions by 30% by 2030, compared to 2020 levels. Methane is responsible for a third of current warming from human activities and is one of the most potent greenhouse gasses.[4]

Agriculture is one of the sectors that are most vulnerable to the impacts of climate change. Changes in temperature and precipitation patterns can result in altered growing seasons, shifts in pest and disease ranges, and decreased soil moisture, all of which can impact crop yields. Extreme weather events such as droughts, heatwaves, and floods can also have significant impacts on agricultural productivity and food security. Climate change is also affecting the world's fisheries and aquaculture, which provide critical protein sources for many people.[5]

The impact of climate change on crop productivity varies depending on factors such as crop type, location, and the magnitude of change in climatic variables. Rising temperatures generally reduce yields, while increasing precipitation may offset or reduce the impact of rising temperatures. In Iran, crop productivity depends on adaptation abilities, climate scenarios, and CO2 fertilization. In Cameroon, a decrease in precipitation or an increase in temperature leads to a significant decrease in farmers' net revenue and has caused fluctuations in national income. In Veracruz, Mexico, statistical evidence shows that coffee yield is affected by temperature and there is a potential 34% reduction in current production. Expanding irrigated areas can increase crop yields but may have a detrimental effect on the environment. Climate change has a greater impact on tropical regions, where crops experience high-temperature stress during elevated levels of temperature, as they remain closer to their high-temperature optima.[6]

Temperature, rainfall, humidity, and wind speed are factors that impact crop yields. In China, climate change might reduce wheat (35%), corn (18%), and rice (45%) yields until 2100.

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[4]United Nations "COP26: Together for Our Planet | United Nations." 2021. https://www.un.org/en/climatechange/cop26.

[5]"Climate Change Impacts on Agriculture and Food Supply | US EPA." 2022. US EPA. December 13, 2022. https://www.epa.gov/climateimpacts/climate-change-impacts-agriculture-and-food-supply#4foot.

[6] Malhi, Gurdeep Singh, Manpreet Kaur, and Prashant Kaushik. 2021. "Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review." Sustainability 13 (3): 1318. https://doi.org/10.3390/su13031318.

Moreover, insect pests and diseases are more common in warm and humid regions.[7] Extreme weather events have increased in frequency since the 1900s in the Netherlands, which has had a significant impact on wheat yield reduction.[8] Due to climate change, an increase in the number of droughts is expected in most regions of the world, Africa is the most vulnerable region. As a result, yields of major crops in drought-affected areas are expected to decline by more than 50% by 2050 and by almost 90% by 2100.[9]

The IPCC warns that climate change is already influencing livestock production through direct impacts on animal mortality rate and productivity from heat stress, as well as indirect impacts on grasslands, species allocation, and diseases. By the end of the age, extreme heat stress risks will increase for all livestock species in many regions of the world, resulting in declines in livestock numbers and milk production. Livestock productivity and fertility will also be harmed by rising temperatures, with animals eating 3 to 5 percent less per additional degree of warming. In the coming century livestock can face additional heat stress throughout the globe, which will affect economic losses. In addition, zoonotic diseases may become more prevalent as the ranges of disease-carrying insects and arthropods expand with warming temperatures. Under the most extreme climate scenarios, one-third of global food production could be pushed beyond the Safe Climatic Space by the end of the century, with regions in top livestock-producing countries such as Brazil, China, and India being most at risk.[10]

However, the agricultural sector is also one of the sources of greenhouse gas emissions into the atmosphere. Agriculture contributes 19-29% of total greenhouse gas emissions, and 1/3 of globally produced food is either lost or wasted. Farming releases methane and nitrous oxide, two powerful greenhouse gases, and these emissions have increased by 14% between 2001 and 2011. While the EU has reduced its agriculture emissions by 24% through the efficient application of fertilizers, better manure management, and a decline in livestock numbers, developing countries are moving in the opposite direction. Innovative techniques like

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[7] Zhang, Peng, Junjie Zhang, and Minpeng Chen. 2017. “Economic Impacts of Climate Change on Agriculture: The Importance of Additional Climatic Variables Other than Temperature and Precipitation.” Journal of Environmental Economics and Management 83 (May): 8–31. https://doi.org/10.1016/j.jeem.2016.12.001.

[8] Powell, J. P., and S. Reinhard. 2016. “Measuring the Effects of Extreme Weather Events on Yields.” Weather and Climate Extremes 12 (June): 69–79. https://doi.org/10.1016/j.wace.2016.02.003.

[9] Li, Yinpeng, Wei Ye, Meng Wang, and Xiaodong Yan. 2009. “Climate Change and Drought: A Risk Assessment of Crop-Yield Impacts.” Climate Research 39 (May): 31–46. https://doi.org/10.3354/cr00797.

[10] Reintjes, Eline. 2022. “Food Systems and Livestock Production Under Climate Change: The IPCC’s Sixth Assessment - FAIRR.” FAIRR. May 3, 2022. https://www.fairr.org/article/food-systems-and-livestock-production-under-climate-change/.

capturing methane from manure, more efficient use of fertilizers, and greater efficiency in meat and dairy production can help reduce emissions from agriculture. Changes in consumption patterns by reducing food waste and avoiding emission-intensive food products can also contribute to cutting the greenhouse-gas emissions of agriculture.[11]

Overview of the Central Asian Region and agricultural sector

Before independence, agriculture was a major sector in the Central Asian countries and considered a significant portion of their GDP and labor force. Today, agriculture remains a significant sector in the region's economy, chipping in between 5.2% to 23.3% of the GDP, and employing 20% to 50% of the labor force depending on the country.[12]

The major agricultural sector in Central Asia varies from country to country, but some of the main agricultural activities in the region include livestock production, crop production, horticulture, and irrigated agriculture. Central Asia has a long history of livestock production, and the sector continues to be an important source of income and employment for many rural communities in the region. Crop production, including cereal, fruit, and vegetable crops, is an important part of agriculture in Central Asia. In some countries, such as Kazakhstan and Uzbekistan, large-scale commercial agriculture is also a substantial portion of the agricultural sector. Horticulture, including the production of fruits, vegetables, and nuts. Central Asia is characterized by a shortage of water resources, which has led to the development of large-scale irrigation systems to support agriculture in the region.[13]

Overall, the major agricultural sector in Central Asia is diverse and includes both traditional and modern forms of agriculture. The region is encountering significant challenges related to water scarcity, soil degradation, and climate change, and there is a need for investment in sustainable agriculture practices to enhance the resilience of the sector to these challenges and promote sustainable agricultural development in the region. With over 70% of the total land area used for agriculture, even a modest climate change can significantly impact the

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[11] "Climate-Smart Agriculture." 2021. World Bank. 2021. https://www.worldbank.org/en/topic/climate-smart-agriculture.
[12] Hamidov, Ahmad, Katharina Helming, and Dagmar Balla. 2016. "Impact of Agricultural Land Use in Central Asia: A Review | FAO." 2016. https://www.fao.org/family-farming/detail/en/c/396435/.
[13] Voca. 2018. "Agriculture in Central Asia: Unlocking the Potential. An Interview with Irna Hofman - Voices On Cental Asia." Voices on Cental Asia. October 12, 2018. https://voicesoncentralasia.org/agriculture-in-central-asia-unlocking-the-potential-interview-with-irna-hofman/.

region's economic output. Although a few studies have explored this issue, there has been limited research on the economic dimensions of climate and agriculture in Central Asia. According to the study "Assessing the Economic Impact of Climate Change on Agriculture in Central Asia," a one-degree Celsius increase in the annual temperature leads to a $4 per hectare growth in agricultural net revenue, equivalent to $117 million in total benefits. However, future climate scenarios suggest a net welfare loss of about $66 million in agriculture by 2040 due to changes in rainfall and temperature.[14]

Central Asia is warming faster than the global average, which makes countries among the most vulnerable to climate change. Over the past three decades the temperature has increased by 0.5 degrees Celsius, by 2085 it may increase by 2 and 5.7 degrees, respectively.[15] More than 60% of the Central Asia region area has a dry climate with minimal rainfall, which makes the region susceptible to rising temperatures. It increases the evaporation of water from the soil and raises the risk of drought. Due to the limited availability of water, many lands, harvest, and organisms in the region are vulnerable to these changes. A recent study published in Geophysical Research Letters reveals that desert climates have expanded north by up to 100 kilometers in parts of Central Asia since the 1980s, as global temperatures rise. The study furthermore found that over the past 35 years, temperatures have increased across all of Central Asia, which includes parts of China, Uzbekistan, and Kyrgyzstan. This expansion of desert climate threatens ecosystems and those who rely on them, including grazing animals and the people who depend on the land for their livelihoods. Additional findings related to how rising temperatures and changing precipitation patterns are affecting glaciers in mountainous regions, specifically the Tian Shan range in northwestern China. The increase in temperature has led to more rainfall than snowfall, resulting in the melting of glaciers at high elevations. This unprecedented shrinking rate of glaciers could impact the flow of meltwater to crops and people in the future as the glaciers will not be replenished with lost ice due to reduced snowfall.[16]

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[14] “Visiting Fellow Program 2020: Assessing Economic Impact of Climate Change on Agriculture – CAREC Institute.” 2020. CAREC Institute -. https://www.carecinstitute.org/publications/visiting-fellow-program-2020-assessing-economic-impact-of-climate-change-on-agriculture/.

[15] “Central Asia Needs to Take More Action on Climate Change Risks | United Nations Development Programme.” 2022. UNDP. https://www.undp.org/kyrgyzstan/press-releases/central-asia-needs-take-more-action-climate-change-risks.

[16] Magazine, Giorgia GuglielmiNature. 2022. “Climate Change Is Turning More of Central Asia into Desert.” Scientific American. June 22, 2022. https://www.scientificamerican.com/article/climate-change-is-turning-more-of-central-asia-into-desert/.

Purpose of the study

This thesis work focuses on the challenges posed by climate change to the livestock sector in the five Central Asian countries of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. In the study, I tried to understand how climate change is affecting the livestock sector and vice versa estimates greenhouse gas (GHG) emissions from livestock production, as well as develop practical strategies and solutions to mitigate its negative impacts and adapt to its inevitable consequences through the agri-food system. The Global Livestock Environmental Assessment Model (GLEAM) tool was used to estimate GHG emissions from livestock, and secondary white and blue papers were used to identify the main trends, policies, and challenges in the field of climate change and agriculture in the region.

Climate change has already affected agricultural productivity, causing changes in the timing and distribution of crops, and leading to increased incidence of pests and diseases. These changes have serious implications for food security, rural livelihoods, and the global economy. Studying the impacts of climate change on agriculture can help to identify the pattern of vulnerable regions, crops, and communities, and develop targeted interventions to support them. It can also help to identify sustainable agricultural practices that can help to mitigate greenhouse gas emissions and adapt to changing conditions.

The thesis is divided into five chapters to analyze the causal relations between climate change and livestock in Central Asia. Chapter 1 contains a review of the literature and highlights the list of articles and reports, as well as a detailed research design of the paper. Chapter 2 focused on the impacts of climate change in the sector, and review regional and global adaptation-mitigation policies in the region. In addition, an overall review of the importance of the agri-food system in climate change mitigation. Chapter 3 is devoted to the assessment of greenhouse gas emissions by livestock using the GLEAM tool and livestock contribution to climate change. Chapter 4 is the study of the best practices of climate change mitigation and adaptation, as well as a list of recommendations regarding funding and agri-food system. Chapter 5 is the conclusion and suggestions for future studies.

CHAPTER I

A. Literature review

Climate change and heat stress pose crucial challenges to livestock production, health, and welfare. Increasing temperatures can lead to losses in dairy and meat production and make livestock more vulnerable to parasites and diseases, as warmer temperatures can boost the lifecycle and population of parasites. Reproductive performance, fertility, and embryonic growth are also at risk of declining, which can lead to a decreasing population of livestock. Indirect effects of climate change include water, forage, and pasture shortages, as well as changes in the pattern of feed crop yields.[17] However, according to the FAO, livestock is responsible for 14.5% of GHG emissions worldwide, primarily due to the release of methane and nitrous oxide during the digestive processes of ruminants, as well as from manure and fertilizers.[18] Additionally, livestock production has numerous negative consequences on natural ecosystems, including deforestation, land degradation, and water pollution. For instance, 75% of the Amazon rainforest has been cleared for grazing land, animal feed crops, and the expansion of the livestock sector.[19] Moreover, the production of beef meat is a significant source of water waste, as it requires 15,415 liters of water to produce just one kilogram.[20] By 2050 global demand for livestock production is estimated to double.[21]

Livestock is an important source of income for local communities, as well as for economic development in many countries and the global food system. Houzer and Scoones argue that livestock doesn't always have a negative impact on nature, but can also be sustainable and profitable depending on the type of animal and management practices employed. Furthermore, the authors argue that estimating GHG emissions from livestock is difficult due to a lack of data, and often the available data is limited to Europe and North America.[22] Richard Twine has the opinion that the FAO's estimation of 14.5% of greenhouse gas

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[17] Singh, Dr. Rajesh. 2022. “Impact of Climate Change on Livestock.” Pashudhan Prahree, June. https://www.pashudhanpraharee.com/impact-of-climate-change-on-livestock-2/.
[18] “Key Facts and Findings.” n.d. FAO. https://www.fao.org/news/story/en/item/197623/icode/.
[19] Bello, Marina. 2022. “Why Cattle Ranching Is the Biggest Deforestation Driver in the Amazon.” Dialogo Chino, September. https://dialogochino.net/en/article/58442-how-cattle-ranching-became-the-biggest-deforestation-driver-in-the-amazon/.
[20] Hussain, Grace. 2022. “How Does Livestock Farming Affect Climate Change?” Sentient Media, November. https://sentientmedia.org/how-does-livestock-affect-climate-change/.
[21] Rojas-Downing, M. Melissa, A. Pouyan Nejadhashemi, Timothy M. Harrigan, and Sean A. Woznicki. 2017. “Climate Change and Livestock: Impacts, Adaptation, and Mitigation.” Climate Risk Management 16 (January): 145–63. https://doi.org/10.1016/j.crm.2017.02.001.
[22] Houzer, Ella, and Ian Scoones. 2021. “Are Livestock Always Bad for the Planet? Rethinking the Protein Transition and Climate Change Debate.” https://doi.org/10.19088/steps.2021.003.

emissions produced by livestock is underestimated.[23] According to him, the actual emissions should be at least 16.5%, because it doesn't take into account deforestation and manure emission. A list of authors wrote articles focused on the effect of climate change on livestock production and the impact of livestock on climate change, as well as a suggested list of recommendations for mitigation and adaptation strategies.[24]

Central Asia is currently facing a significant challenge in developing a professional human capital capable of advocating for and consulting on climate change activities, risks, and strategies, both for society and the government. The region's climate is changing rapidly, with consequences that could have severe impacts on the economy, environment, and social stability of the countries in the area. However, despite the urgency of the situation, the topic of climate change in Central Asia has seen a lack of academic research and related activities. Between 1991 and 2021, the eight key journals for Central Asia research published 13,488 journal articles, but only 33 (0.24%) were related to climate change.[25] Additionally, authors have identified 292 peer-reviewed and gray literature publications, 165 in natural science, 89 in social science, and 38 technical reports. These publications have mainly focused on water resources, economic impacts, and poverty. Overall, global climate change requires research and data at the regional and local levels for a deep understanding of the magnitude of the impact and consequences of the problem (FAO, 2008). This can aid in the formation of a collective understanding of the importance of climate change, which is necessary for expanding interventions and making policy decisions to overcome its consequences.

Climate change and agriculture are complex issues that require a holistic approach to mitigation and adaptation by different actors, sectors, and methods. According to the FAO's Technical Report (2008), adaptation refers to the adjustment of natural and anthropogenic systems in response to the actual or expected effects of climate change. To combat poverty, reduce natural degradation, loss of biological diversity and ecosystems, and improve adoption capacity and food production chains within the framework of sustainable development. Climate change mitigation requires human intervention to reduce the sources of climate

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[23] Twine, Richard. 2021. “Emissions from Animal Agriculture—16.5% Is the New Minimum Figure.” Sustainability 13 (11): 6276. https://doi.org/10.3390/su13116276.
[24] Cheng, Muxi, Bruce A. McCarl, and Chengcheng Fei. 2022. “Climate Change and Livestock Production: A Literature Review.” Atmosphere 13 (1): 140. https://doi.org/10.3390/atmos13010140.
[25] Vakulchuk, Roman, Anne Sophie Daloz, Indra Overland, Haakon Fossum Sagbakken, and Karina Standal. 2022. “A Void in Central Asia Research: Climate Change.” Central Asian Survey, May, 1–20. https://doi.org/10.1080/02634937.2022.2059447.

change and greenhouse gas emissions by improving livestock waste management, diet, and digestibility, as well as improving animal genetics and breeding efficiency).[26]

The world is currently encountering challenges in global and regional supply chains, agriculture, and nutrition. In his work, Edward R. Carr (2022) delves into the potential of deliberate, transformative systemic changes in agriculture for achieving adaptation, low-emission development, and inclusive sustainable development outcomes. Agriculture and the food system encompass a range of activities and individuals involved in the production, processing, transportation, and consumption of food, fiber, and energy derived from nature.

B. Research design

Climate change is a complex issue that requires analysis from different perspectives and approaches. This study will use a mixed research method focused on the convergent parallel design to build a holistic understanding of the topic. The sources for the qualitative method include "gray literature," academic journals, and articles that provide insight into the current situation in the region and the extent of the impact of climate change on the livestock sector. In the Qualitative part, I used FAO's Global Livestock Environmental Assessment Model (GLEAM-i) tool to estimate and model GHG emissions in the region. FAO's technical note "Low carbon livestock development in Kyrgyzstan" was used as a sample for this study, to generate a GHG-decreasing model through agri-food systems.

Objectives

- Identify the main impacts and consequences of climate change on the livestock sector.
- Estimate and generate a low GHG emission model by using the GLEAM-i tool.
- Propose a low GHG emission strategy of development through improving agri-food systems to Central Asia

Modeling and GLEAM-i

[26] "What Is the Difference between Adaptation and Mitigation?" n.d. European Environment Agency. https://www.eea.europa.eu/help/faq/what-is-the-difference-between#:~:text=In%20essence%2C%20adaptation%20can%20be,(GHG)%20into%20the%20atmosphere.

GLEAM is a tool that helps stakeholders implement more sustainable livestock management practices by assessing the interaction between livestock and the environment. GLEAM 3.0 is the latest version, which includes improvements and updates such as new animal distribution maps, new crop layers, updated emission calculation methods, nitrogen modeling, updated methodology for land use change and representation of animals in feedlots, adjustment of emissions and parameters for feeds sold on the international market, updated distances and emissions for international shipping and a new method for calculating emissions after production on the farm.

GLEAM is a process-based model that uses a life cycle assessment system to estimate greenhouse gas emissions in livestock systems and distribute them across various commodities. It covers 11 major livestock products on a global scale and provides spatially accurate estimates of emissions and production of goods broken down by production systems, which allows you to calculate the intensity of emissions at various spatial scales. The model is based on six modules that work together in a certain sequence to calculate emissions and production: the herd module, the feed ration and consumption module, the animal emissions module, the manure module, the feed emissions module and the distribution module.[27]

Assessment scenarios generated based on the online version of FAO GLEAM-i database from 2015 and comparative data represent improved data of the agri-food system. The scenarios included improvements in types of feeding, and manure management method. The target farm for analysis is dairy cattle, meat goats, and sheep in Central Asia, the production system and orientation for all animals are grassland pasture and mixed. The assessment considers three main gases such as carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). The result in GLEAM-i is presented as a total emissions ton CO2 equivalent per year, emission intensity t CO2 equivalent per protein, protein production ton protein per year, as well feed consumption ton dry matter per year.

[27] “Resources | Global Livestock Environmental Assessment Model (GLEAM) | Food and Agriculture Organization of the United Nations.” n.d. https://www.fao.org/gleam/resources/en/.

CHAPTER II

A. Current understanding of the impacts of climate change on Central Asian agriculture

The Central Asian region boasts a diverse landscape, with varying climates and contrasting natural features across different countries, making it difficult to estimate the effects of climate change on each sector. The region is located in arid and semi-arid zones and has a diverse landscape including grasslands, rangelands, ice caps, forests, deserts, lakes, and rivers. However, extreme weather events and climate change can affect the ecosystem of the countries through glacial melting, drought, decreased precipitation, degraded biodiversity, deforestation, and shrinking rivers.[28].

Over the last century (1901-2016), there has been a significant increase in annual mean temperatures in Turkmenistan (15.07°C) and Uzbekistan (12.21°C), with a similar pattern observed in Kazakhstan (5.78°C), Tajikistan (3.30°C), and Kyrgyzstan (2.13°C). From 1901 through 2013, temperatures increased by 0.12°C per decade. In the last 30 years, this annual temperature has increased up to 0.45°C.[29] By the end of the century, temperatures might continue to increase, especially in the southern part of Central Asia, which may see 90-150 warm days per year.[30]

Impact of climate change on Livestock

[28] "Climate Risk Profile: Central Asia." 2018. Global Climate Change. March 31, 2018. https://www.climatelinks.org/resources/climate-risk-profile-central-asia.
[29] ICRC, 2021. Central Asian climate fact sheet. https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.climatecentre.org/wp-content/uploads/RCCC-ICRC-Country-profiles-Region_Centra_Asia.pdf&ved=2ahUKEwj67-na17j-AhXWt6QKHeDuDJ4QFnoECAoQAQ&usg=AOvVaw32-t3fZSqQFdP2TvPDKxPX
[30] Reyer, Christopher P. O., Ilona M. Otto, Sophie Adams, Torsten Albrecht, Florent Baarsch, Matti Cartsburg, Dim Coumou, et al. 2017. "Climate Change Impacts in Central Asia and Their Implications for Development." Regional Environmental Change 17 (6): 1639–50. https://doi.org/10.1007/s10113-015-0893-z.

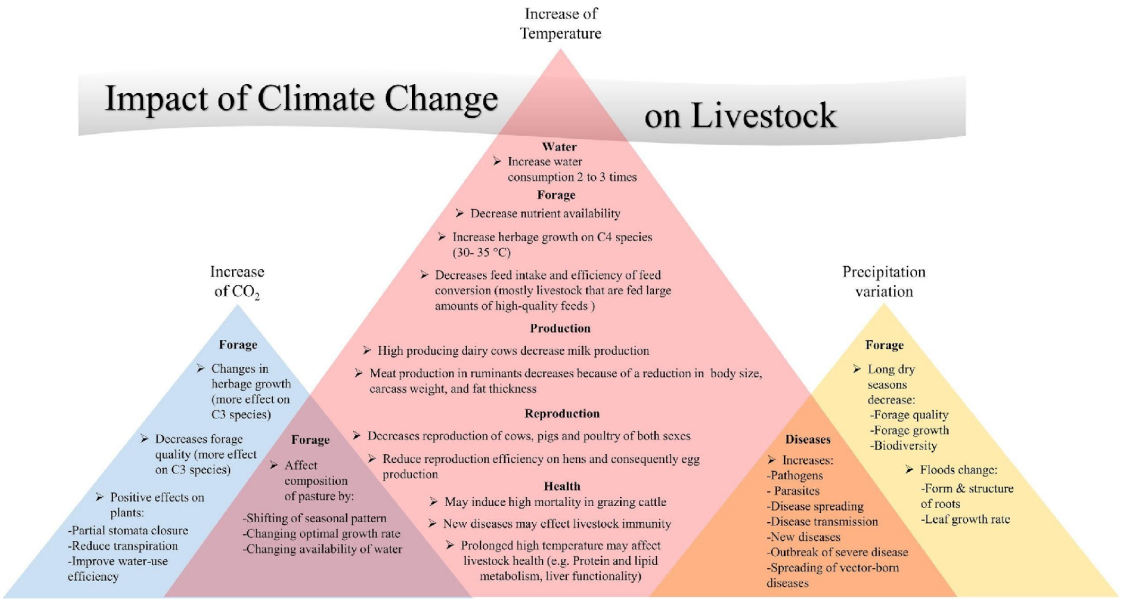

Figure 1: Illustration of impact of climate change on livestock by Melissa, 2017

Climate change has effects on different aspects of livestock, which can be identified as direct and indirect effects. Indirect effects impact the metabolism, immune system, productivity, and physical and psychological health of the animals. Meanwhile, direct effects impact the livestock's environmental conditions, such as the availability of water and grassland, feed production, pest production, and seasonal variations.[31]

*Direct effect*s

The main challenge and consequence of Climate Change to livestock is heat stress. Usually, mammals' and bird's body temperature is higher than the ambient temperature, if the ambient temperature is high then animals start sweating and painting to normalize body temperature. This leads to negative consequences of level of production, disease, age, body condition, and hair coat characteristics. Dairy-producing cows are most vulnerable to heat stress which leads to decreased feed and water intake and reduced milk synthesis.[32] Heat stress negatively affects the appetite and feed intake of domestic animals, and decreases their production of meat, milk, and eggs, especially for dairy cows and goats, when the temperature is above

[31] Cheng, McCarl, and Fei. 2022. "Climate Change and Livestock Production: A Literature Review." Atmosphere 13 (1): 140. https://doi.org/10.3390/atmos13010140.
[32] Collier, Robert J., Lance H. Baumgard, R.B. Zimbelman, and Yao Xiao. 2019. "Heat Stress: Physiology of Acclimation and Adaptation." Animal Frontiers 9 (1): 12–19. https://doi.org/10.1093/af/vfy031.

their thermal comfort zone of 25-26°C.[33]. Increasing the temperature above 20 to 35°C decreases the feed intake of hogs by 11%);[34] decreases the percentage of fat (39.7%), solid-not-fat (19%), and protein in the milk.[35] Meat production and feedlot cattle are the most vulnerable to losing body mass, fat thickness, muscle, and meat quality.

High temperature and humidity have negative effects on the reproductive performance of both male and female animals by disrupting various tissues, organs, and reproductive rhythms.[36] Heat stress affects the reproductive system of female animals by reducing the duration and intensity of estrus. Additionally, an increase in temperature of 40°C reduces the growth of follicles, leading to non-viability. High temperatures also increase the secretion of adrenocorticotropic hormone and cortisol, which can block sexual behavior.[37] As well it can also change the sexual behavior of bulls and reduce the quality of sperm and fertilization of the oocyte. To obtain fertile sperm, the testes of a bull should be 2-6°C times colder than body temperature.[38]

Such heat stress affects the fertility of animals, reduces the development and maturation of the oocyte, and increases the risk of miscarriage and infertility, especially during summer and autumn.[39]. In the early stages of embryo development and formation, high temperature adversely affects the survival and development of the fetus.[40]

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[33] Kadzere, C.T., Michael R. Murphy, Nissim Silanikove, and Ephraim Maltz. 2002. "Heat Stress in Lactating Dairy Cows: A Review." Livestock Production Science 77 (1): 59–91. https://doi.org/10.1016/s0301-6226(01)00330-x.

[34] Lopez, J. a. Rodriguez, George R. Jesse, Bradley A. Becker, and Mark R. Ellersieck. 1991. "Effects of Temperature on the Performance of Finishing Swine: I. Effects of a Hot, Diurnal Temperature on Average Daily Gain, Feed Intake, and Feed Efficiency." Journal of Animal Science 69 (5): 1843–49. https://doi.org/10.2527/1991.6951843x.

[35] Kadzere et al. (2002b). "Heat Stress in Lactating Dairy Cows: A Review." Livestock Production Science 77 (1): 59–91. https://doi.org/10.1016/s0301-6226(01)00330-x.

[36] Amundson, J. L., Terry L. Mader, Richard J. Rasby, and Qi Hu. 2006. "Environmental Effects on Pregnancy Rate in Beef Cattle1." Journal of Animal Science 84 (12): 3415–20. https://doi.org/10.2527/jas.2005-611.

[37] Ozawa, Kimiyoshi, Kenji Hashimoto, Takashi Kishimoto, Eiji Shimizu, Hiroshi Ishikura, and Masaomi Iyo. 2006. "Immune Activation During Pregnancy in Mice Leads to Dopaminergic Hyperfunction and Cognitive Impairment in the Offspring: A Neurodevelopmental Animal Model of Schizophrenia." Biological Psychiatry 59 (6): 546–54. https://doi.org/10.1016/j.biopsych.2005.07.031.

[38] Cardozo, J.A., Marta Fernández-Juan, Fernando Forcada, A Abecia, Teresa Muiño-Blanco, and José A Cebrián-Pérez. 2006. "Monthly Variations in Ovine Seminal Plasma Proteins Analyzed by Two-Dimensional Polyacrylamide Gel Electrophoresis." Theriogenology 66 (4): 841–50. https://doi.org/10.1016/j.theriogenology.2006.01.058.

[39] Singh, Rajesh. 2022. "Impact of Climate Change on Livestock." Pashudhan Prahree, June. https://www.pashudhanpraharee.com/impact-of-climate-change-on-livestock-2/#content.

[40] Edwards, Joanne, and Peter Hansen. 1996. "Elevated Temperature Increases Heat Shock Protein 70 Synthesis in Bovine Two-Cell Embryos and Compromises Function of Maturing Oocytes1." Biology of Reproduction 55 (2): 340–46. https://doi.org/10.1095/biolreprod55.2.341.

An increase in temperature can positively affect the rate and amount of spread of parasites and diseases among animals. It is difficult to simulate the spread of parasites as they can be affected by wind direction, rainfall, drought, or soil moisture. In a nested and warm environment, the life and cycle of midges, mosquitoes, ticks, and flies increase, as does the number, which leads to the rapid spread of diseases.[41] Thermal stress and diseases can significantly undermine the immune system of livestock, by reducing resistance to diseases, environmental changes, and further health problems.[42] Additional heat stress increases mortality rates among dairy cows and pigs, especially high temperature is dangerous in a humid environment of more than 50% with temperatures above 37.7 °C.[43]

Indirect effects

The indirect effects of climate change lead to significant changes not only for livestock but also destabilize the favorable habitat of many species of animals and plants. The high concentration of CO2 and O3 in plant products leads to a decrease in the content of minerals and protein in seeds, which reduces the quality of animal feed. Overall high levels of CO2 decrease the concentration of minerals by about 8% in rice and wheat.[44] Climate change reduces the yield of most crops with local warming by 1-2 ° C, especially corn and wheat. [45]

High temperatures lead to rapid evaporation of water, drought, and water scarcity, which reduces the amount of harvest. Approximately, temperatures above 30°C–34°C reduce grain yields in conditions of water shortage, destroying the development of crops and cells of plants. The combination of high temperature and evaporation of water quickly dries the soil and destroys most seeds.[46] Also, in hot conditions, the consumption of drinking water by

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[41] Paull, Sara H., Thomas R. Raffel, Bryan E. LaFonte, and Pieter T. J. Johnson. 2015. "How Temperature Shifts Affect Parasite Production: Testing the Roles of Thermal Stress and Acclimation." Functional Ecology 29 (7): 941–50. https://doi.org/10.1111/1365-2435.12401.
[42] Bagath, Madiajagan, Govindan Krishnan, C. Devaraj, V. P. Rashamol, Prathap Pragna, A. M. Lees, and Veerasamy Sejian. 2019. "The Impact of Heat Stress on the Immune System in Dairy Cattle: A Review." Research in Veterinary Science 126 (October): 94–102. https://doi.org/10.1016/j.rvsc.2019.08.011.
[43] Spain, James, Jeffrey Keown, and Barry Steevens. 1993. "How to Reduce Heat Stress in Dairy Cattle." MU Extension. 1993. https://extension.missouri.edu/publications/g3620.
[44] Loladze 2014b. "Hidden Shift of the Ionome of Plants Exposed to Elevated CO2 Depletes Minerals at the Base of Human Nutrition." ELife 3 (May). https://doi.org/10.7554/elife.02245.
[45] IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
[46] Carlson, Richard Eugene. 1990. "Heat Stress, Plant-Available Soil Moisture, and Corn Yields in Iowa: A Short- and Long-Term View." Journal of Production Agriculture, July. https://doi.org/10.2134/jpa1990.0293.

livestock can increase by 50% at temperatures above 30 ° C).[47]In addition, climate change is the cause of extreme weather events and cataclysms in the world such as storms, floods, fires, unstable precipitation, and droughts, which can have a negative impact on livestock.

Central Asia region

Central Asia is a landlocked region with different landscapes, Kazakhstan, Turkmenistan, and Uzbekistan occupy plains and partly mountains, while Kyrgyzstan and Tajikistan occupy more than 90% of the High Tien Shan and Pamir mountains. The climate zone is arid and semi-arid with a continental and extreme climate, where winters are cold (-18 °C) and summers are hot (+50°C max). In the northern part of the region, there is more grassland, steppe, and semi-desert vegetation with a higher distribution of precipitation in spring and autumn than in the south. Precipitation begins in October and peaks in March and April. The southern region has desert vegetation, and agriculture is possible only with irrigation, this region mainly includes Turkmenistan and southern Uzbekistan.[48]

Animal husbandry in Central Asia is associated with economic and social factors, such as obtaining a small income, savings, and large commercial organizations. However, after gaining independence in 1991, the countries faced the challenges of defining a strategy for sustainable development in the livestock sector.[49] The total area of Central Asia is about 400 million hectares, but only 20% of them are suitable for agriculture, while the rest are deserts and mountainous areas.[50]According to FAO, the total amount of water in the region is 221.3 × 109 m3, mainly in the Alps and groundwater. Kyrgyzstan and Tajikistan are upstream countries and account for 80% of Central Asia's water resources. Kazakhstan, Turkmenistan, and Uzbekistan, downstream countries with middle and lower reaches of rivers, have smaller water resources.[51]

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[47] Ward and McKague. " Ministry of Food, Agriculture, and Rural Affairs." 2019. http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm.
[48] Carol. "Planning and Policies on Extensive Livestock Development in Central Asia." 1996.. https://odi.org/en/publications/planning-and-policies-on-extensive-livestock-development-in-central-asia/.
[49] Robinson, Sarah. 2020. "Livestock in Central Asia: From Rural Subsistence to Engine of Growth?" ResearchGate, May. https://www.researchgate.net/publication/341204278_Livestock_in_Central_Asia_From_rural_subsistence_to_engine_of_growth.
[50] Bobojonov, Ihtiyor, and Aden Aw-Hassan. 2014. "Impacts of Climate Change on Farm Income Security in Central Asia: An Integrated Modeling Approach." Agriculture, Ecosystems & Environment 188 (April): 245–55. https://doi.org/10.1016/j.agee.2014.02.033.
[51] Zhao, Yuhan, Yongxun Zhang, Xiande Li, and Chen Qian. 2022. "Assessment on Land-Water Resources Carrying Capacity of Countries in Central Asia from the Perspective of Self-Supplied Agricultural Products." Land 11 (2): 278. https://doi.org/10.3390/land11020278.

However, there are several problems related to water resources in the region, due to climate change, insufficient drainage, and mass extraction of water for irrigation from the Amu Darya and Syr Darya rivers, Kazakhstan and Uzbekistan are facing a decrease in the area of the Aral Sea. This has led to drastic changes in the local landscape and fauna, the dried-up territories of the Aral Sea often raise dust storms, which are dangerous for local inheritance. The second problem is the melting of snow reserves and glaciers in the Tien Shan and Pamir mountains that in the long term may lead to water shortages and irrigation disasters.[52] Over the past couple of decades, Central Asia has faced two of the strongest droughts in history in 2000-2001 and 2007-2008, which have damaged the socio-economic life of countries, especially Tajikistan, destroying more than a third of the croplands.[53]. Over the past century, global temperatures have increased by 0.74 °C, which means that most of the arid areas of the mid-latitudes can dry out quickly during the summer. Moreover, since the 1990s, temperatures have been rising rapidly in Central Asia and it has become the most prone to drought since the region is located in one of the world's arid zones)[54]. By estimation global temperature warming of +1.5 °C may reach by 2039, and temperature warming of +2°C by 2059.[55]

Kazakhstan

Kazakhstan is the largest country in the region that has faced land degradation due to unstructured land use, conversion to arable land, and grazing. Over the years 1900-2000, the yield of crops in the district decreased from 23.4 to 10.7 million tons, and the number of livestock decreased from 48.6 million to 14.5 million heads. The main system of animal husbandry is based on various Soviet-style feedlots. However, in the eastern part of Kazakhstan, pastures in remote areas, and ecological zones that move livestock from lower altitudes to higher ones are popular. Other owners of private ranches may not be able to graze

[52] Hamidov, Helming, and Balla. 2016b. “Impact of Agricultural Land Use in Central Asia: A Review.” Agronomy for Sustainable Development 36 (1). https://doi.org/10.1007/s13593-015-0337-7.
[53] Lioubimtseva, Elena, and Feng Gao. 2009. “Climate and Environmental Change in Arid Central Asia: Impacts, Vulnerability, and Adaptations.” Journal of Arid Environments 73 (11): 963–77. https://doi.org/10.1016/j.jaridenv.2009.04.022.
[54] Jiang, Liangliang, Guli Jiapaer, Anming Bao, Hao Guo, and Felix Ndayisaba. 2017. “Vegetation Dynamics and Responses to Climate Change and Human Activities in Central Asia.” Science of the Total Environment 599–600 (December): 967–80. https://doi.org/10.1016/j.scitotenv.2017.05.012.
[55] Liu, Yang, Xiu J Geng, Zhixin Hao, and Jianping Zheng. 2020. “Changes in Climate Extremes in Central Asia under 1.5 and 2 °C Global Warming and Their Impacts on Agricultural Productions.” Atmosphere 11 (10): 1076. https://doi.org/10.3390/atmos11101076.

in remote areas.[56] Most of the territory is flat and located below 500 m above sea level, more than 80% is covered with deserts and steppes.

Uncontrolled withdrawal of water from rivers and lakes can lead to an increase in desolation, as happened with the Aral Sea, due to an increase in the area of irrigated agricultural land from 4.3 to 8.2 million hectares. Taking into account climate change and environmental challenges, Kazakhstan will face water shortage and expansion of drylands.[57] One of the other problems is related to the degradation of the heads of saigas (antelopes), which appeared 20 thousand years ago and are now under threat of extinction. Climate change and environmental degradation reduce the number of saigas by 3-10 times compared to the 1 million population.[58]

Kyrgyzstan

Kyrgyzstan is located at an altitude of more than 1500 meters above sea level, and about 90% of the territory is surrounded by mountains. Most of the ecosystem, resources, and environment have been adopted for mountainous areas, but this has made the country vulnerable to climate change, landslides, and earthquakes.[59]

Animal husbandry occupies an important place for the local population in terms of the livelihood and income of small and medium-sized businesses. Thus, about 83% of the agricultural territory is used for pastures, and the rest of the territory is used for growing crops. The grazing system in the country is based on altitude, depending on the season, cattle move from a low altitude to a high one (Bekturov, 2020). The livestock population has rapidly declined from 15 million head after independence to 15 million head of cattle, but currently, the number of livestock has increased from previous numbers. Moreover, currently, 45% to 70% of pasture lands and soil have degraded, due to the fact that livestock did not

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[56] Kolluru, Venkatesh, Ranjeet John, Jiquan Chen, Meghann Jarchow, Reza Goljani Amirkhiz, Vincenzo Giannico, Sakshi Saraf, Khushboo Jain, Maira Kussainova, and Jing Yuan. 2022. "Untangling the Impacts of Socioeconomic and Climatic Changes on Vegetation Greenness and Productivity in Kazakhstan." Environmental Research Letters 17 (9): 095007. https://doi.org/10.1088/1748-9326/ac8c59.

[57] Zhupankhan, Aibek, Kamshat Tussupova, and Ronny Berndtsson. 2018. "Water in Kazakhstan, a Key in Central Asian Water Management." Hydrological Sciences Journal-Journal Des Sciences Hydrologiques 63 (5): 752–62. https://doi.org/10.1080/02626667.2018.1447111.

[58] MZh, Nurushev. 2017. "How to Save the Saiga in Kazakhstan?" КиберЛенинка. 2017. https://cyberleninka.ru/article/n/how-to-save-the-saiga-in-kazakhstan.

[59] Egemberdiev, A. 2020. "Pasture Reform and Its Implementation in Kyrgyzstan." UKnowledge. 2020. https://uknowledge.uky.edu/igc/22/3-3/6/.

migrate over long distances.[60] Kyrgyzstan is one of the most climate-sensitive countries in Eastern Europe and Central Asia. Global warming has led to the melting of glaciers and a shortage of fresh water. In addition, there has been little precipitation recently, the country is suffering from drought and aridity of mountain pastures. Economic losses from damage to agriculture and water reached 64% of the total economy of the country.[61]

Tajikistan

Tajikistan is one of the Central Asian landlocked countries located in the southeastern part of the region. The country is mountainous, almost 93% of the territory is covered by the ranges of the Pamir and Tien Shan mountain systems, whose height varies from 1000 to 3000 meters. Agriculture takes an important place in rural areas, with around 65% of the population involved in the agriculture sector. However, less than 30% territory is agricultural land, and more than 75% is used for pasture and grazing use.[62] Tajikistan has a mixed population of sheep, goats (3 million), and cattle (1 million).

Tajikistan is also one of the countries vulnerable to climate change, global warming, reduced precipitation, evaporation of water, and melting of glaciers. The country is facing various types of land degradation, such as soil, salinization, and loss of organic minerals, 90% of pastures have degraded and suffer from erosion).[63] Tajikistan and Kyrgyzstan face similar environmental and climate change problems, and the temperature rise in this region may be even higher than the global average temperature. By 2100, the temperature may reach +3 °C, and +3.7 °C, which will change mountain ecosystems, degraded and dry pastures, hay fields, and grain crops. Even now, countries are experiencing a shortage of good feed in winter.[64].

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[60] Schickhoff, Udo. 2020. “Pastoral Resources in the Naryn Oblast, Kyrgyzstan, under Post-Soviet Transformation : Effects of Livestock Grazing on Vegetation and Soils.” Ediss.Sub.Hamburg. October 19, 2020. https://ediss.sub.uni-hamburg.de/handle/ediss/8051.

[61] Park, Sugyeong, Chul Hee Lim, Sea Jin Kim, Erkin Isaev, Sol-E Choi, Sung Koo Lee, and Woo-Kyun Lee. 2021. “Assessing Climate Change Impact on Cropland Suitability in Kyrgyzstan: Where Are Potential High-Quality Cropland and the Way to the Future.” Agronomy 11 (8): 1490. https://doi.org/10.3390/agronomy11081490.

[62] Lerman, Zvi. 2011. “Tajikistan’s Vulnerability to Climate Change.” ResearchGate, July. https://www.researchgate.net/publication/254385974_Tajikistan's_Vulnerability_to_Climate_Change.

[63] Bockel, Louis. 2015. “Ex-Ante GHG Appraisal of the Environmental Land Management and Rural Livelihoods Project in Tajikistan...” ResearchGate, September. https://doi.org/10.13140/RG.2.1.2263.5603.

[64] Kerven, C., Bernd Steimann, Chad Dear, and Laurie Ashley. 2012. “Researching the Future of Pastoralism in Central Asia’s Mountains: Examining Development Orthodoxies.” Mountain Research and Development 32 (3): 368–77. https://doi.org/10.1659/mrd-journal-d-12-00035.1.

Turkmenistan

Turkmenistan has a cold desert and cold semi-arid climate with hot and dry temperatures (maximum +40 °C) and little precipitation from January to April[65]. 80% of the territory of the country is occupied by the Karakum desert, and 65% of the land is under threat of desertification. Despite natural resources such as oil and gas, the remaining local communities are heavily dependent on agriculture and animal husbandry for their livelihoods and basic small income. However, due to the lack of grasslands, most of the available areas are overpopulated.[66]

According to forecasts, by the 2090s, the average temperature in Turkmenistan may rise by +3 °C, +5.1°C. Therefore, the risk of land degradation and drought in the country is very high, which can affect the availability of water and pasture lands.[67]

Uzbekistan

Agriculture is the main sector of the economy where the country processes cotton and wheat for export. The second type of economic activity is based on animal husbandry, especially on karakul sheep, goats, horses, and camels, which provide meat (20%), milk (10%), wool (40%), and sheepskins. In most rural areas, manure is used as fertilizer, biomass, and heat energy.[68] After the collapse of the Soviet Union, Uzbekistan was the only country in which the number of livestock did not decrease, moreover, it stabilized and increased by 1.5 times. Currently, animal husbandry accounts for 40% of the gross national agricultural production.[69]

The consequences of climate change in Uzbekistan have not been studied in depth, but it is obvious that this has a negative impact on heat stress in the livestock sector. Uzbekistan is located downstream of the river, and a decrease in precipitation and a shortage of water

[65]Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. & Steinfeld, H. 2013. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome.

[66] Annaklycheva, Jamal. 2002. “Combating desertification in Turkmenistan on the grass roots level example of the Central Karakum Desert - Kölner UniversitätsPublikationsServer.” Universität Zu Köln. 2002. https://kups.ub.uni-koeln.de/343/.

[67] Climate Risk Country Profile: Turkmenistan (2021): The World Bank Group and the Asian Development Bank

[68] Toderich, Kristina, Igor Massino, Ismail Shoaib, and Sergey Usmanov. 2008. “Utilization of Agriculture Residues and Livestock Waste in Uzbekistan.” ResearchGate, January. https://www.researchgate.net/publication/5161701_Utilization_of_Agriculture_Residues_and_Livestock_Waste_in_Uzbekistan.

[69] Romagnoli, Stefano, Augusto Faustino, Adilov S, and Hasanov Shavkat. 2022. “Uzbekistan: A Report on Livestock Production and the Provision of Veterinary Services.” ResearchGate, September. https://www.researchgate.net/publication/363940159_Uzbekistan_a_report_on_livestock_production_and_the_provision_of_veterinary_services.

resources can cause damage at the country level to degraded pastures, acreage, and drought.[70] Significant climate change and warming are marked in the Aral sea zone, the number of days with temperatures above 40 °C doubled. Similar temperature increases are observed in the rest of 32-70% of the territories, and about 12% in the foothills.[71]

B. Review of mitigation and adaptation strategies in the Central Asian region

Regional and global cooperation is an integral part of sustainable development and the fight against climate change, which begins with a common understanding of the current problem, future solutions, and goals. Central Asian countries actively participate in international conventions and take part in strategies and agreements related to climate change. Since the 1990s, all Central Asian countries have ratified the United Nations Framework Convention on Climate Change (UNFCCC), a global treaty on preventing human interference in the climate system and stabilizing greenhouse gas concentrations.[72] Central Asia has also signed and ratified the second global treaty, the Paris Agreement, which aims to maintain the global average temperature below 1.5 °C pre-industrial levels. The strategy of the Paris Agreement includes components of financing, technical support, and capacity building to reduce greenhouse gas emissions and increase resilience to climate change, taking mitigation measures.[73]

The Central Asian Government also cooperates with a list of international organizations of UN branches in the field of adaptation of agriculture and animal husbandry to climate change and mitigation of its consequences. The Food and Agriculture Organization (FAO) is an intergovernmental organization that plays a huge role in providing expertise on agriculture, nutrition, animal husbandry, crop production, and forestry for the countries of Central Asia.

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[70] Abdullaevich, Faizullaev Maqsud. 2023. “THE MAIN CHARACTERISTICS OF THE DEVELOPMENT OF THE LIVESTOCK NETWORK IN THE REPUBLIC OF UZBEKISTAN.” February 11, 2023. https://interonconf.org/index.php/ger/article/view/2010.

[71] Salokhiddiov, A, Poshoazimkhon Khakimova, M. Ismailov, R Razzakov, and J Mirzaqobulov. 2020. “Impact of Climate Change on Irrigated Agriculture in Steppe Zones of Uzbekistan.” IOP Conference Series: Materials Science and Engineering 883 (1): 012073. https://doi.org/10.1088/1757-899x/883/1/012073.

[72] “United Nations Framework Convention on Climate Change.” 1992. UNTC. 1992. https://treaties.un.org/pages/ViewDetailsIII.aspx?src=IND&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&clang=_en.

[73] UNFCCC. n.d. “The Paris Agreement Related News Related Documents Related Links What Is the Paris Agreement?” https://unfccc.int/process-and-meetings/the-paris-agreement#:~:text=The%20Paris%20Agreement%20is%20a,force%20on%204%20November%202016.

FAO works closely with the Government, active citizens, and the local population on issues of sustainable development and food safety.[74] UNDP plays an important role in promoting and informing about the causes and consequences of climate change in different sectors, as well as promoting sustainable development, equality, and poverty reduction in the region.[75].

International and regional banks also play important roles in the financial and technical support of the agriculture sector. The World Bank assists and supports the economic and social development of rural areas of Central Asia by providing financial and technical support in various sectors, including water, climate change, and energy[76]. The European Bank for Reconstruction and Development (EBRD) is the largest institutional investor in Central Asia, which provides financial and technical support to agricultural small-medium enterprises and businesses within the framework of the climate change strategy. Focused on the promotion of environmental protection, water, and energy efficiency.[77] The Asian Development Bank (ADB) also plays an important role in combating climate change and eliminating the consequences of environmental disasters in the agricultural sector.[78]

At the country level, governments have taken individual steps to prevent the impact of climate change on agriculture, livestock, land, and pasture degradation. By improving irrigation and pasture management, increasing the resilience of small farmers to global warming or other direct and indirect activities. Each country has its strategy to counter climate change, aimed at the sustainable development of animal husbandry, early warning information, and mobilization of knowledge, technology, and resources.

Kazakhstan is one of the world's largest countries with greenhouse gas emissions, in which more than 80% of electricity is generated from coal and which accounts for 82% of greenhouse gas emissions. In 2013, the President of Kazakhstan set a goal to transfer 50% of

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[74] "FAO in Europe and Central Asia." n.d. REU. https://www.fao.org/europe/about-us/fao-in-europe-and-central-asia/en.
[75] UNDP. n.d. "About the Region | United Nations Development Programme." UNDP. https://www.undp.org/eurasia/about-us/about-region.
[76] World Bank Group. 2023. "World Bank in Central Asia." World Bank. https://www.worldbank.org/en/region/eca/brief/central-asia.
[77] EBRD. 2018. Where we work in Central Asia. https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.ebrd.com/documents/comms-and-bis/the-ebrd-in-central-asia.pdf&ved=2ahUKEwio9az0-db-AhXwxAIHHeJlAHwQFnoECBIQAQ&usg=AOvVaw3Nqz3sQCBgR62ypXBRSg-1
[78] Ralph. 2023. "What We Do." Asian Development Bank. May 10, 2023. https://www.adb.org/what-we-do#:~:text=The%20Asian%20Development%20Bank%20(ADB,advisory%20services%2C%20and%20knowledge%20support.

energy resources to the use of renewable energy sources by 2050.[79]. In 2023, Kazakhstan will adopt another ambitious strategy to achieve carbon neutrality by 2060 by modifying and transforming all economic activities in the country following the goals of net zero carbon emissions.[80]

Greenhouse gas emissions in Kyrgyzstan are low, but the government is striving to further reduce emissions from business, fossil fuels, coal, and energy. Moreover, the government plans to increase the use of renewable energy sources and try to achieve carbon neutrality by 2050.[81] In the agricultural culture sector, the authorities focused on the "green" economy, increasing the yield of climate-resistant crops and livestock, improving grazing, and the efficiency of fertilizer application[82]. In the National Development Strategy of the Kyrgyz Republic for the period 2018-2040, the Government focused on protecting the environment, creating an environmentally friendly and educated society in the whole country.[83]

Tajikistan has a detailed written plan to prevent and protect agriculture and the environment from the consequences of climate change, such as drought, floods, landslides, and degradation. The National Climate Change Adaptation Strategy for the period up to 2030 is aimed at reducing yields and crop losses during the season of drought and disease, protecting land and pasture degradation, and improving the irrigation system and storage management. In addition, it supports regional and local food prices for farmers, as well as organizes research, and provides farmers with information and equipment.[84]

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[79] "Energy and Environment | Kazakhstan | U.S. Agency for International Development." 2022. U.S. Agency For International Development. June 1, 2022. https://www.usaid.gov/kazakhstan/energy-and-environment#:~:text=Kazakhstan%20proposed%20as%20its%20Nationally,fulfilment%20of%20the%20proposed%20target.

[80] World Bank Group.. "Kazakhstan Discusses Ways for Achieving Carbon Neutrality and Building Resilience." World Bank, March 1, 2023. https://www.worldbank.org/en/news/press-release/2023/02/28/kazakhstan-discusses-ways-for-achieving-carbon-neutrality-and-building-resilience.

[81] "Kyrgyz Republic's Climate Plan Invites International Cooperation." 2021. UNDP Climate Promise. 2021. https://climatepromise.undp.org/news-and-stories/kyrgyz-republics-climate-plan-invites-international-cooperation.

[82] International Monetary Fund. Middle East and Central Asia Dept. 2023. "Climate Change Adaptation and Mitigation in the Kyrgyz Republic." Imfsg, February. https://doi.org/10.5089/9798400232725.002.A002.

[83] FAO. 2018. "National Development Strategy of Kyrgyz Republic for the period of 2018-2040." 2018. https://www.fao.org/faolex/results/details/fr/c/LEX-FAOC209953/#:~:text=of%202018%2D2040.-,National%20Development%20Strategy%20of%20Kyrgyz%20Republic%20for%20the%20period%20of,creation%20of%20productive%20jobs%2C%20transition.

[84] "National Strategy for Adaptation to Climate Change of the Republic of Tajikistan for the Period up to 2030. | UNEP Law and Environment Assistance Platform." 2019. October 2, 2019. https://leap.unep.org/countries/tj/national-legislation/national-strategy-adaptation-climate-change-republic-tajikistan.

In 2021, Turkmenistan updated a new national strategy on climate change and declared to reduce and stabilize GHG emissions by 2030 through the promotion of sustainable agriculture, renewal, and clean energy. As well as improve agriculture and water infrastructure, especially the irrigation system. Moreover, the government at the legislative level is trying to support farmers and small businesses, to develop human and technical potential in the face of climate change.[85]

Uzbekistan is one of the least responsible for climate change, as the country has increased its obligations under the Paris Climate Agreement by more than 300 percent. However, the government plans to reduce greenhouse gas emissions per unit of GDP by 35% by 2030 and move forward to carbon neutrality through a "green" economy and the development of the electronic power industry.[86] In addition, the state plans to improve water resources management in all sectors of the economy, organize training and capacity-building activities in the field of green economy and climate change, and mitigate the impact of the Aral Sea on the environment.[87]

C. General overview of the role of the agri-food system

The agri-food system is a broad interconnected process and activities of different actors starting from processing, and production and ending with distribution and consumption. It includes farmers, ranchers, fishermen, consumers, plants, and animals themselves. The agri-food system not only includes physical aspects like growing, harvesting, and selling but also encompasses political, economic, and social activities. Moreover, it's also about techniques and approaches to managing water, land, biodiversity, and environmental resources.[88]

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[85] "National Strategy of Turkmenistan on Climate Change | United Nations Development Programme." 2021. UNDP. 2021. https://www.undp.org/turkmenistan/publications/national-strategy-turkmenistan-climate-change.

[86] "People and Government of Uzbekistan Take Action to Confront the Climate Crisis Collectively." 2021. UNDP Climate Promise. 2021. https://climatepromise.undp.org/news-and-stories/people-and-government-uzbekistan-take-action-confront-climate-crisis-collectively.

[87] Kholbadalov, Utkirjon, Marco Mantovanelli, and Leela Raina. 2023. "In Uzbekistan, Policy Dialogue Builds Momentum for Transition to a Green Economy." World Bank Blogs (blog). May 19, 2023. https://blogs.worldbank.org/climatechange/uzbekistan-policy-dialogue-builds-momentum-transition-green-economy.

[88] "2022 Global Food Policy Report: Climate Change and Food Systems - World." 2022. ReliefWeb. May 15, 2022. https://reliefweb.int/report/world/2022-global-food-policy-report-climate-change-and-food-systems.

The Intergovernmental Panel On Climate Change's sixth Assessment Report highlights the importance and vulnerability of the agri-food system in the face of high emissions and climate change. In the middle of the century, due to the unstable climate, the food supply chain, and the high intensity of production, 10% of the suitable crop and livestock area will be under pressure. This can lead to the increasing price for storage, of agro products, reducing income and emergence of conflicts and migration in volunaribele regions.[89].

One of the important goals of this century is to transform the agri-food system on a sustainable basis for future generations in order to provide affordable quality nutrition and diets around the world. Taking into account the ecological condition of the ecosystem, to extract and provide food resources without harm to the environment. In 2022, the United Nations (UN), which deals with food security and nutrition in the world, reported that 29.3% of the world's population suffers from malnutrition, which has serious consequences for human physical and mental health. Moreover, the future of the agri-food system is under the pressure of climate change, water scarcity, and land degradation.[90]

Agri-food chains can be divided into several major sectors as primary production, processing, packaging, distribution, market, customers, and waste stream. The Agri-food chain can be divided into several main sectors such as primary production, processing, packaging, distribution, market, customers, and waste stream.

The primary production stage begins with the production of crops and livestock in farms and ranches, which involves planting crops, and seeds and raising animals. After comes cutting, harvesting, cleaning, and slaughtering, to prepare the first stage of safe consumption. Depending on the product and approach of the local actors, the next important stage is packaging which helps to protect and preserve the product in good quality during transportation. During packaging can be used bags, boxes, container pallets, and other wrapping materials. The next step is logistics and distribution of products that include a collection of raw materials and ready products and distribution to the market and customers. The market includes local and international retailers, groceries, supermarkets, and commercial merchants. Waste also occupies an important part in this system, which helps not only to earn extra money and reduce costs but also helps nature to protect against the

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[89] Climate Change Impacts and Adaptation Options in the Agrifood System. 2022. FAO EBooks. https://doi.org/10.4060/cc0425en.

[90] “UN Report: Global Hunger Numbers Rose to as Many as 828 Million in 2021.” 2022. Newsroom, June. https://www.fao.org/newsroom/detail/un-report-global-hunger-SOFI-2022-FAO/en.

senseless waste of resources. Waste can be edible and inedible, edible is the remains of parts of meat, or fish that can be used for further addition to other products and additives. Inedible parts go to feed animals and plants.[91]

[91] "What Is Processed Food?" 2023. EUFIC. 2023. https://www.eufic.org/en/food-production/article/what-is-processed-food.

CHAPTER III

A. Impact of livestock on climate change

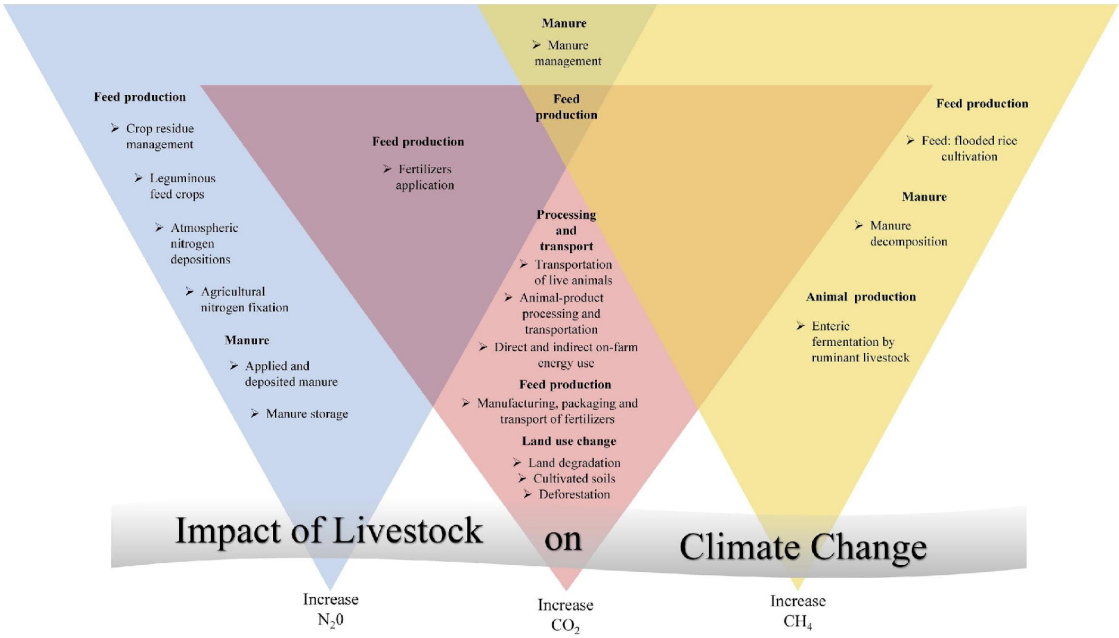

Figure 2: Illustration of the impact of livestock on climate change by Melissa, 2017

Livestock plays a significant role in the contribution of anthropogenic GHG's emissions gases to the atmosphere of the globe since it is production and cultivation requires huge amounts of natural resources to produce and grow. The main primary emitting gases from livestock are methane and nitrous oxide, as well as indirectly generated CO2 during the transportation and processing of agricultural products. It's difficult to calculate the actual GHG emissions in the livestock sector, but recent publications and reports highlight the high contribution of agriculture emissions.[92]

The global total emission from agrifood systems accounts for around ~21-37% of annual emissions.[93] Moreover, this number is expected to increase in the near future, according to the forecast, by 2050 the share of demand for meat and dairy products will increase to 76% and 65%, respectively, compared with the baseline level of 2005-2007.[94]

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[92] Lynch, John, Michelle Cain, David J. Frame, and Raymond T. Pierrehumbert. 2021. "Agriculture's Contribution to Climate Change and Role in Mitigation Is Distinct From Predominantly Fossil CO2-Emitting Sectors." Frontier 4 (February). https://doi.org/10.3389/fsufs.2020.518039.

[93] Schmale, Julia, Silvia Henning, J. S. Henzing, Helmi Keskinen, Karine Sellegri, Jurgita Ovadnevaite, Aikaterini Bougiatioti, et al. 2017. "Collocated Observations of Cloud Condensation Nuclei, Particle Size Distributions, and Chemical Composition." Scientific Data 4 (1). https://doi.org/10.1038/sdata.2017.3.

[94] Froggatt, Antony, Laura Wellesley, and Rob Bailey. 2014. "Livestock – Climate Change's Forgotten Sector: Global Public Opinion on Meat and Dairy Consumption." Chatham House, December.

From the statistical perspective of greenhouse gas emissions by livestock, Methane (CH4) is the highest with a contribution of 44%, in second place close to each other is Nitrous oxide 29% and 27% Carbon Dioxide (CO2) which affect the global warming in the earth.[95]. Livestock digestion, fermentation, and manure storage produce high levels of methane gas which is 28 times more dangerous than CO2 in 100 years time period, and 80 times higher in 20 years time period. Approximately depending on the quality of feed, region, and type of animal, one ruminant per day can produce 250-500 L of methane.[96] Last, but not least gas is Nitrous oxide, produced from livestock manure, urine, and organic/inorganic fertilizers. The concentration of N2O in the atmosphere is around 6% with a lifespan of 120 years. However, the impact of climate change is 265 times higher than the impact of CO2.[97]

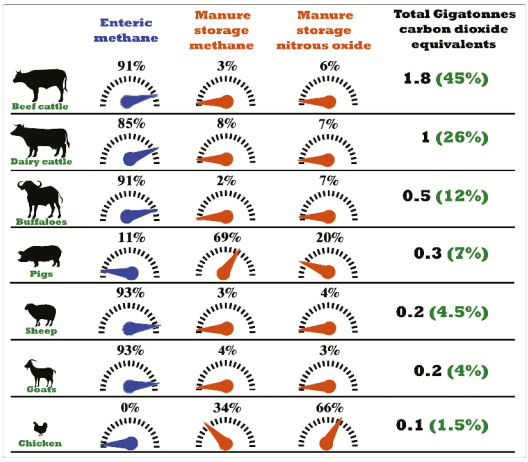

Figure 3: Illustration of Greenhouse gas emissions from intestinal fermentation and manure storage by animal species, expressed in gigatons of carbon dioxide equivalents. Designed by Grossi, source FAO, 2017

Figure 1 shows that ruminants have a high level of enteric methane, while pigs and chickens have a high level of methane emissions during the storage of manure and nitrous oxide. Out of all groups, cattle take a major part emission of total gigatons carbon dioxide equivalent.[98]

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https://www.chathamhouse.org/publication/livestock-climate-change-forgotten-sector-global-public-opinion-meat-and-dairy.

[95] Opio, C., Gerber, P., Mottet, A., Falcucci, A., Tempio, G., MacLeod, M., Vellinga, T., Henderson, B. & Steinfeld, H. 2013. Greenhouse gas emissions from ruminant supply chains – A global life cycle assessment. Food and Agriculture Organization of the United Nations (FAO), Rome

[96] "Agriculture and Aquaculture: Food for Thought | US EPA." 2023. US EPA. February 27, 2023. https://www.epa.gov/snep/agriculture-and-aquaculture-food-thought#:~:text=A%20single%20cow%20produces%20between,(Our%20World%20in%20Data).

[97] Rivera, Julián, and Julián Chará. 2021. "CH4 and N2O Emissions From Cattle Excreta: A Review of Main Drivers and Mitigation Strategies in Grazing Systems." Frontier 5 (October). https://doi.org/10.3389/fsufs.2021.657936.

[98] FAO . 2017. Global Livestock Environmental Assessment Model (GLEAM). Rome (Italy): Food and Agriculture Organization of the United Nations (FAO).

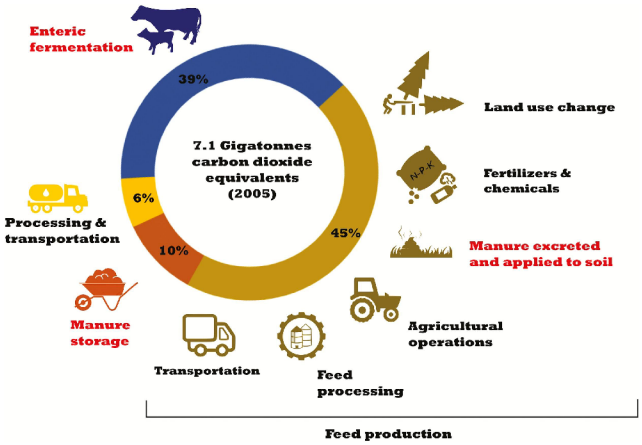

Figure 4: Illustration of Livestock emissions, direct livestock emissions are indicated in red

In the next figure, we can see GHG's emissions by livestock sectors and sources. Almost half of the emissions are generated as a result of feed production, maintaining the viability and rearing of animals, through such processes as feed processing, agricultural operations, fertilization, and land use.[99] The second source of emission is enteric methane produced by microbial fermentation of animals. Low levels of feed and nutrition increase level of the enteric methane.[100] A small part of the emissions is accounted for by the storage of manure, which emitted GHG through two methods. The first method is the storage of manure, especially in liquid form. The second method is to use manure as energy for cooking and heating which produce black carbon.[101]

Moreover, livestock is the cause of several environmental degradations such as deforestation, water pollution, and land and pasture degradation in the world. In the period from 1990 to 2000, the area of forestry exceeded twice the area of Portugal that had been exceeded in the area of pastures. Mass cleaning of forestry leads to the loss of biodiversity, species, and ecosystem.[102]

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[99] Gerber, P. J., H.Steinfeld, B.Henderson, A.Mottet, C.Opio, J.Dijkman, A.Falcucci, and G.Tempio. 2013. Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Rome: FAO. Available from http://www.fao.org/3/a-i3437e.pdf

[100] Min, Byeng-Ryel et al. "Enteric Methane Emissions and Animal Performance in Dairy and Beef Cattle Production: Strategies, Opportunities, and Impact of Reducing Emissions." Animals : an open access journal from MDPI vol. 12,8 948. 7 Apr. 2022, doi:10.3390/ani12080948

[101] S. O. Petersen, M. Blanchard, D. Chadwick, A. Del Prado, N. Edouard, J. Mosquera, S.G. Sommer,
Manure management for greenhouse gas mitigation,Animal, Volume 7, Supplement 2, 2013, Pages 266-282, ISSN 1751-7311, https://doi.org/10.1017/S1751731113000736

[102] Dopelt, Keren et al. "Environmental Effects of the Livestock Industry: The Relationship between Knowledge, Attitudes, and Behavior among Students in Israel." International journal of environmental research and public health vol. 16,8 1359. 16 Apr. 2019, doi:10.3390/ijerph16081359

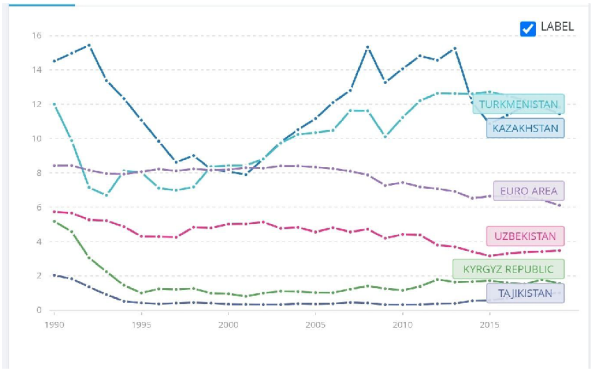

Figure 5: CO2 emissions (metric tons per capita): Source World Bank[103]

The main major source of greenhouse gas emissions in Central Asia is still the energy sector, during the Soviet Union Kazakhstan was supplied with coal, Turkmenistan with oil, and Uzbekistan with gas.

In the present, patterns have not changed much, since energy is still the main contributor to GHG emissions. From the graph above, we can see that the oil-based energy industry in Kazakhstan and Turkmenistan has two times higher CO2 emissions than the European area. In Kazakhstan, almost 80% of CO2 emission comes from the extraction and processing of fossil fuels. The second largest country in terms of greenhouse gas emissions in Central Asia is Turkmenistan, where 95% of emissions are from the energy sector. Emissions are expected to increase due to planned gas and oil production activities. The main greenhouse gas emissions in Uzbekistan are again accounted for by fossil fuels, energy, and the construction industry - about 73%. In addition, the country has a high level of methane emissions in the chemical industry, mining, and agriculture. Kyrgyzstan and Tajikistan have the lowest greenhouse gas emissions in the region, as most of the energy is generated from hydropower and water resources. However, it still has a variety of emission sectors, such as transport, utilities, agriculture, and land use.[104]

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[103] "World Bank Open Data." 2020. World Bank Open Data. 2020. https://data.worldbank.org/indicator/EN.ATM.CO2E.PC?end=2019&locations=KZ-KG-TJ-UZ-TM-XC&name_desc=true&start=1990&view=chart.

[104] UNDP, Human Development Report 2007/8: Fighting climate change: Human solidarity in a divided world. New York. https://hdr.undp.org/content/human-development-report-20078

B. Estimation of the environmental impacts of the livestock sector and greenhouse gas emissions in Central Asia: The Global Livestock Environmental Assessment Model (GLEAM) tool.

This section describes the process of estimating greenhouse gas emissions in animal husbandry across all five Central Asian countries. The FAO's GLEAM-i online platform utilizes the most up-to-date databases collected in 2015 to estimate emissions in these countries. The emission results obtained for each country in 2015 will be compared with the data from the scenario in order to enhance the accuracy of the agri-food system implementation.

GLEAM-i consists of three emission modules presented as a herd, each comprising various parameters such as animal numbers, live weight, fertility, mortality, and production. The first module encompasses animal-related parameters, the second module focuses on feed parameters and the type of livestock being raised, while the last module deals with manure management. In the scenarios developed for the agri-food system (AFSystem), the changes primarily revolve around feed parameters and the approach to manure management. It is important to note that the parameters within the "Herd" module have remained unchanged. However, this does not mean that the production activity, the death rate or the birth rate will not change.

Feed

The feeding practices in central Asia dependent on various animal species included a combination of crop residues, hay or silage from alfalfa, grass, and legumes, as well as some silage from grain plants. The primary source of food in the spring and summer for most species is fresh grass obtained through grazing, during the winter season is feedlot. However there are high relationships between quality of feed and methane production, for instance certain types of feed, such as grasses and hays, lead to more methane production compared to concentrates like corn.[105]

The improved feeding plan introduced several changes, including the use of crop residues from sugar beet and maize instead of residues from other grains. Maize and sugar beet have

[105] CLEAR Center. “How Can Cattle Feed Additives Reduce Greenhouse Gas Emissions?,” November 29, 2021. https://clear.ucdavis.edu/explainers/how-can-cattle-feed-additives-reduce-greenhouse-gas-emissions.

lower enteric methane and nitrous oxide emissions.[106] However sugar beet, which is not primarily grown for feed, was added to make up approximately 5% of the animal diets. However, its use is limited due to its high potassium content. The feeding of silage from whole grain plants and crop residues from rice to cattle was highly reduced, rice crop reduced approximately half of the original sources. Production of the rice uses a lot of natural resources such as water and land, and has a high level of global methane emissions.[107] There was also a slight decrease in quantity of the crop residues from wheat and hay or silage from alfalfa. Instead of reduced silage, rice and wheat, the feeding plan included an increased amount of silage from maize plants, fodder beet, grains, fresh mixture of grass and legumes. The overall adjustment aimed to align with a pasture improvement strategy and an expected increase in higher quality fodder crops. These changes aimed to optimize the animal diets and enhance feeding efficiency.

Manure management

Emissions of nitrous oxide (N2O) and methane (CH4) from manure are highly variable and influenced by numerous factors, which makes it challenging to implement simultaneous mitigation strategies for both gases. However, several practices show promise in reducing emissions while enhancing carbon capture and improving food production. These strategies include implementing silvopastoral systems (integrating trees and pasture), adopting practices that enhance soil quality and coverage, and utilizing nitrogen-fixing plants. Different studies suggest that these strategies can lead to reductions of up to 50% in CH4 or N2O emissions from manure, depending on the specific method and production system employed.[108] In the estimation almost total management system distributed between daily spread and composing, and only 10% to the solid storage. Daily spreading of manure required to apply to cropland and pasture during 24 hours. Composting required to store and compost before applying it as fertilizer.

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[106]https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.pggrc.co.nz/files/154319600485.pdf&ved=2ahUKEwjPwvbi8vz-AhUZgf0HHXuVBhMQFnoECBQQAQ&usg=AOvVaw1eThrdXJKe3Wy2IWFr9Dc4

[107] United Nations Environment Programme. “Rice May Be Cheap, but Production Comes at a Cost.” UNEP, n.d. https://www.unep.org/news-and-stories/story/rice-may-be-cheap-production-comes-cost.

[108] Rivera, Julián Esteban, and Julian Chará. 2021. “CH4 and N2O Emissions from Cattle Excreta: A Review of Main Drivers and Mitigation Strategies in Grazing Systems.” Frontiers in Sustainable Food Systems 5 (October). https://doi.org/10.3389/fsufs.2021.657936.

C. Analysis and interpretation of the output of the Global Livestock Environmental Assessment Model (GLEAM) tool

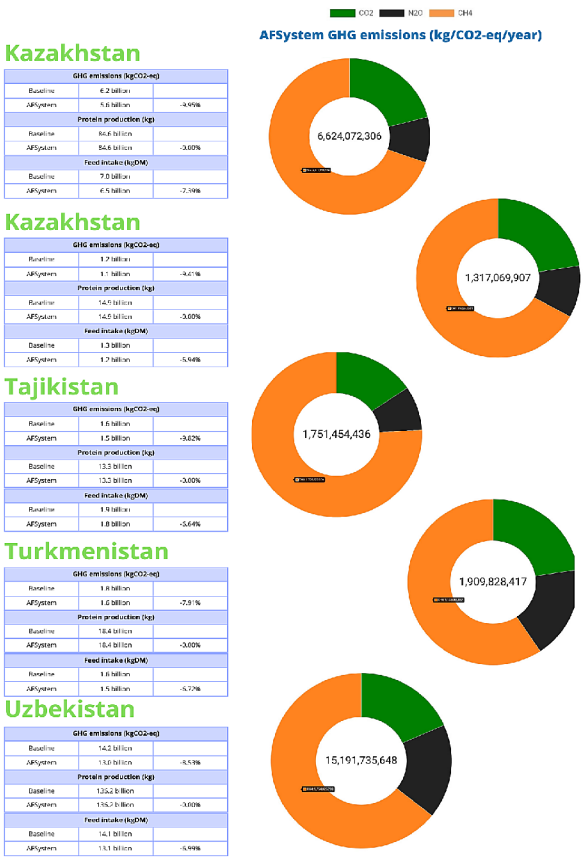

Figure 6: Results of estimation GHG (kgCO2-eq) under agri-food system, estimated by online platform GLEAM-i

The highest GHG'S emission country from livestock is Uzbekistan with the 15 billion kgCO2-eq emission, second one is Kazakhstan with 6 billion, and the rest Kyrgyzstan, Tajikistan and Turkmenistan have 1 billion kgCO2-eq each.

The Agri-food system scenario on GLEAM-i reveals a noteworthy reduction in greenhouse gas (GHG) emissions for each Central Asian country, with an impressive decline of around 8%. This reduction is equivalent to a substantial decrease of 1-2 billion kgCO2-eq. However, among the different types of emissions, CH4 remains the primary gas contributing to the overall emission. Furthermore, the scenario indicates a 7% decrease in feed intake compared to the baseline data. This means that cattle are consuming less food while still obtaining the same amount of energy.

As results of GLEAM-i shown to effectively mitigate the impact of the livestock sector on global warming, can be achieved by several measures, including animal relocation, enhancing animal feed practices, and improving manure management through composting and daily spreading.

One approach is to consider relocating animals to areas that are more suitable for their specific needs. This could involve moving them to regions with better climatic conditions or optimizing their housing and grazing patterns. By ensuring animals are in environments that promote their well-being, we can potentially reduce the greenhouse gas emissions associated with their production.

Additionally, improving animal feed practices can have a significant impact on reducing the environmental footprint of the livestock sector. Research and investment in sustainable and efficient feed options, such as utilizing alternative protein sources or optimizing feed formulations, can help minimize the emissions generated during feed production and digestion.

Furthermore, implementing effective manure management strategies is crucial. Instead of traditional methods that contribute to methane emissions, adopting composting techniques can help convert manure into valuable fertilizer while minimizing greenhouse gas release. Additionally, spreading the composted manure on a daily basis, rather than allowing it to accumulate, can further reduce its environmental impact.

By combining these measures—relocating animals to suitable areas, improving feed practices, and implementing efficient manure management—we can make significant strides in decreasing the livestock sector's contribution to global warming.

CHAPTER IV

A. Role of agricultural emission reductions in the adoption and mitigation of climate change

In developing countries, agriculture plays a significant role in providing livelihoods, economic and social activities at all levels of society. Therefore, international, and regional organizations and government agencies are actively involved in the development of protection and mitigation strategies in agriculture under the influence of climate change. Agriculture is one of the major contributors to GHG emissions and at the same time also heavily impacted by it. Mitigation of agriculture can significantly decrease global emissions and stabilize global warming. As well as adaptation of agriculture to climate change has a lot of benefits for food security, sustainable agricultural development, and economic sustainability. Protect the environment from soil, land, and pasture degradation, safe biodiversity, and ecological system of regions.

Within the UN Framework Convention on Climate Change meetings develop efficient strategies, policies, and approaches for adaptation and mitigation to climate change. This chapter will cover best practices and policies on adaptation and mitigation of agriculture to climate change at the international and country level. A concept of efficient management practices based on several pillars as involving and using knowledge and experience of indigenous local communities in the strategic planning. Developing low-cost strategies with multiple benefits that include microcredit and financing small stakeholders by taking into account gender, age, and nationality sensitivities.[109]

Agriculture is a broad and complex sector which is why the developing and implementing process should include multidisciplinary and multisectoral actors and institutions. Moreover, decisions and actions should be based on the relevant research taking into account methodologies as well. Adoption and mitigation of agriculture to climate change should be holistic and conceptual by increasing the resilience of the poor population that mainly depends on natural resources to break down hunger and poverty, especially in rural areas. As mentioned by the World Bank, investment in agriculture countries with dependency on agriculture is 3 times more effective than any other sector. Therefore public and private investment is important to build resilient agriculture development for especially smallholder

[109] FAO. 2008. “CLIMATE CHANGE ADAPTATION AND MITIGATION IN THE FOOD AND AGRICULTURE SECTOR.” 2008. https://www.fao.org/3/au034e/au034e.pdf.

farmers. Overall collaboration of state institutions, private companies, and organizations is important to create sustainable interventions in the sector.[110]

Adoption and mitigation strategies can significantly reduce GHG emissions and increase the productivity of the livestock sector. Improve the efficiency of extraction and exploitation of natural resources and protect them from degradation. Adoption requires environmental, social, and economic adjustment to reduce the negative impact of climate change through changes in ecological and human activities. In the livestock sector, it can be achieved through animal responses, human strategy, and management actions.[111]

Adoption

Genetic modification of animals

Since ancient times, breeding and crossing different types of species from the same family have been popular, so it gave genetically modified breeds and took strong genes from their parents. In our case, it is also possible to genetically cross different types of breeds to get a breed resistant to hot climates and climate changes. For example, smaller and lighter pores of animals are more resistant to climatic stress and more productive.[112]

Physical improvement

The improvement of the environment for animals is also one of the ways of adaptation. For animals grazing outdoors, it is possible to effectively build a place to rest with shade such as meadows and pastures, which protects direct sunlight and reduces body temperature and sweating in animals. In dry climates, humidification of the air by spraying water is effective. It is also possible to combine these two methods to improve the effect of shadow and spread. For animals that are kept indoors, ventilation and air conditioning will be effective to cool the room.[113]

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[110] FAO. 2015. “Climate Change and Food Security: Risks and Responses.” FAODocuments. 2015. https://www.fao.org/publications/card/en/c/82129a98-8338-45e5-a2cd-8eda4184550f/.
[111] Cheng, M.; McCarl, B.; Fei,C. Climate Change and LivestockProduction: A Literature Review. Atmosphere 2022, 13, 140. https://doi.org/10.3390/atmos13010140
[112] Bernabucci, U.; Lacetera, N.; Baumgard, L.H.; Rhoads, R.P.; Ronchi, B.; Nardone, A. Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal 2010. https://www.sciencedirect.com/science/article/pii/S175173111000090X?via%3Dihub
[113] Huynh, T.T.T. Heat Stress in Growing Pigs: Wageningen University and Research. 2005. Available online: https://www.proquest.com/docview/2449468017/abstract/BAD39E82C2B7419EPQ/

Pest management

Pest control is effective only in an integrated approach or for prevention. Since the private execution of priorities, injections, and medications negatively affects the animal's body, especially in large doses. And also harmful organisms develop immunity, which can lead to an outbreak of severe plague. Therefore, this method cannot be used as one of the main methods of adaptation to climate change.[114]

Livestock management

Animal husbandry management can be effective not only for animal husbandry but also for the environment. For example, species diversification reduces the spread of plague, overuse of pastures and increases farm sustainability. In addition, the integration of animals into different habitats reduces the risk of degradation of forests and pastures and improves the biological cycle of the environment.[115]

Mitigation

To stabilize global warming, it is important to develop a mitigation strategy in the livestock sector since livestock produces significant greenhouse gas emissions. The mitigation process includes feeding methods, manure management, promoting carbon sequestration, improving animal health and welfare, reducing food waste, and promoting alternative sources of protein. The goal of animal husbandry mitigation is to reduce the environmental impact of animal husbandry and contribute to global efforts to mitigate the effects of climate change.

Pasture management

In the traditional method of dividing livestock, pastures, and meadows receive the main damage. The mitigation strategy should include improving the animal breeding system, not overloading pastures, and systematically changing from place to place. Systematic rotation of cattle from one place to another place will help the pasture to recover. It may be necessary to reduce the number of livestock and the management of new breeds of animals.

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[114] Thornton, P.K.; Van de Steeg, J.; Notenbaert, A.; Herrero, M. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. https://www.sciencedirect.com/science/article/abs/pii/S0308521X09000584?via%3Dihub

[115] Megersa, B.; Markemann, A.; Angassa, A.; Ogutu, J.O.; Piepho, H.-P.; Zárate, A.V. Livestock diversification: An adaptive strategy to climate and rangeland ecosystem changes in southern Ethiopia. https://link.springer.com/article/10.1007/s10745-014-9668-2

Enteric Management

As mentioned previously, the main source of methane is the enteric fermentation of ruminants, which can be reduced through dietary management and nutrition. For instance, improving the quality of the forage can decrease enteric methane emissions by 2.5–15% per unit of milk produced. Additionally, supplying ruminants with bio additional vitamins, grain, and antibiotics also positively efaffectseducing emissions.[116]

Manure Management

Livestock manure generates both N2O and CH4 emissions during storage and handling. The practice and implementation of alternative forms of storage can reduce energy consumption and give benefits. Manure can produce natural biogas by anaerobic digestion and decomposition of microorganisms. This can indirectly reduce emissions by 30% compared to traditional approaches. Moreover, it could use alternatives to fossil energy.[117]

Fertilizer management

Fertilizers and chemicals are often used in the production of forage crops, which leads to an increase in NO2 emissions. Mitigation and adaptation measures for forage crops may include plant breeding and genetic modification. Another way is to use microbial

proteins as a feed substitute. Microbiological proteins can replace about 19% of natural feed, which reduces the amount of gases by 7%.[118]

Carbon sequestration

State's strategic plan should include a part of carbon sequestration in different sectors of society and economy that can be put into practice as part of the policy. Since carbon sequestration requires a conceptual and structural approach that can be achieved by reducing deforestation, planting trees, using high-yielding crops, improving land and water

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[116] Beauchemin, K.A. Dietary Mitigation of Enteric Methane from Cattle. CAB Rev. 2009, 4. Available online: http://www.cabi.org/cabreviews/review/20093276253

[117] Battini, F.; Agostini, A.; Boulamanti, A.K.; Giuntoli, J.; Amaducci, S. Mitigating the environmental impacts of milk production via anaerobic digestion of manure: Case study of a dairy farm in the Po Valley. https://www.sciencedirect.com/science/article/abs/pii/S0048969714002125?via%3Dihub

[118] Pikaar, I.; Matassa, S.; Bodirsky, B.L.; Weindl, I.; Humpenöder, F.; Rabaey, K.; Boon, N.; Bruschi, M.; Yuan, Z.; Van Zanten, H.; et al. Decoupling Livestock from Land Use through Industrial Feed Production Pathways. https://www.nature.com/articles/nclimate2754

management, and introducing rotation grazing management. For instance, Massy planted 50,000 native trees and shrubs under the project "Drawdown" that can help to sequester around 10 tons of CO2 per acre per year. "Drawdown" project is already recognised and implemented in Mexican, Brazilian and Australian policy.[119]

Early warning system and risk management

Climate change and global warming are bringing great uncertainty to weather conditions. Agriculture is largely dependent on weather conditions and precipitation, which make the sector volunaribble. The early warning and risk management system can provide reliable information about the expected weather temperature, prerequisites that can be used to delay planting, fertilizing and harvesting. In addition, it can help farmers prepare for weather-related risks such as droughts, floods and storms.[120]

B. Mitigation and adaptation practices of the other countries

IFAD, together with local communities and government agencies, has implemented several projects on adaptation and mitigation of livestock breeding to climate change. Projects aimed at early warning systems, practicing blogs and improving grazing management. Most projects had a beneficial effect on the sustainability of the development of agriculture and the reduction of carbon dioxide.[121]

The International Fund for Agricultural Development (IFAD) supported two projects to promote the use of biogas as an environmentally friendly energy source in rural areas of China. At the first stage a number of training and seminars were held on the use and practice of biogas in the home. The second stage of the project was the construction of bio-gas installations for the conversion of human and animal waste into methane and carbon dioxide for lighting and cooking. Over the entire period, 2.73 million biogas tanks were built in one

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[119] Zeldovich, Lina. 2021. “Can Cows Help Mitigate Climate Change? Yes, They Can!” JSTOR Daily, May. https://daily.jstor.org/can-cows-help-mitigate-climate-change-yes-they-can/.
[120]Cooper, Ashley. 2019. “Adaptation Framework Thematic Brief: Livestock.” 2019. https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.ifad.org/documents/38714170/42258938/Adaptation%2BFramework%2B-%2BThematic%2BBrief%2B-%2BLivestock.pdf/07ebe276-8a40-86a3-8865-038ccf423bc8&ved=2ahUKEwjr66WxpvD-AhUD8rsIHb0tA_QQFnoECBMQAQ&usg=AOvVaw0DiTNARgnIlWQpUyi8mJIr.
[121] Calvosa, Chiara. n.d. “Livestock and Climate Change.” IFAD. https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.uncclearn.org/wp-content/uploads/library/ifad81.pdf&ved=2ahUKEwiYuPGh1_D-AhWZ8rsIHf2ADCIQFnoECBgQAQ&usg=AOvVaw3HikZrGO8QJcC6Ny5ORxsZ.

of the project locations, which saves for the local community 7.65 million tons of standard coal and 13.4 million tons of firewood per year. In another location in Guangxi, 2.73 million biogas tanks were built, which helps to save 7.65 million tons of standard coal and 13.4 million tons of firewood annually.

In Ethiopia, implemented an early warning system project to improve the conditions and development of pastoral communities living in arid and semi-arid lowlands. The project aimed at an early warning system and plans to prepare for climate disasters to strengthen the resilience of the rural areas and increase their ability to cope with external shocks. Established funds to finance and invest an early warning system, mitigation, and preparation for natural disasters.

In Mongolia was implemented a project on "Strengthening pastoralists' resilience and capacity to adapt to climate variability and extremes" that aimed to improve rangeland, and strengthen herder resilience to natural calamities and magnitude of climate hazards due to global warming. IFAD provided winter fodder, emergency fund and construction remote rangeland addressed climate change and supporting activities to manage natural resources, and introduced index-based insurance to better respond to climate change risks in the livestock sector.

The World Bank, within the framework of the countries' strategy, integrates a Climate-smart agriculture approach to agriculture to improve food security, and climate change resilience strategies through the management of livestock, arable land, and forests. Climate-smart agriculture is distinguished by focusing on the fight against climate change, systematically considering synergies and trade-offs, and seeking to exploit new funding opportunities.[122] By implementing Climate-smart agriculture, it is possible to improve food safety, increase incomes, reduce vulnerability to climate-related risks, and achieve lower emissions, while avoiding deforestation and identifying ways to absorb carbon from the atmosphere. Climate-smart agriculture is implemented in the list of continents and countries around the world.

In Bangladesh, the World Bank implemented a complex and multifunctional project for reducing the effects of climate change on livestock health and productivity, improving

[122] World Bank. 2021. Climate-smart agriculture
https://www.worldbank.org/en/topic/climate-smart-agriculture

feeding, west, and manure management. As well as introducing new technology in the processing of milk and transportation.

In Morocco under the framework of the Climate-smart Agriculture projects implemented capacity-building activities among youth to increase involvement in sustainable economics, the market, and the environment. Similar capacity-building activities have been organized in Brazil, where the World Bank provided technical assistance and educational activities to 20 000 beneficiaries. Educational training focused on the low-carbon agriculture approaches, and practices of sustainable land management.

Colombia has demonstrated another best practice by introducing forest grazing systems and sustainable cattle breeding practices. With the help of technical assistance and effective landscape shaping, achieved significant benefits for the environment and farmers. Since 2010, as part of a 10-year project, 38,390 hectares of pasture lands have been transformed into a system of forest pastures. Compared with a site without a system of plantations, the productivity of milk on a site with a system of plantations increased by 25%, the cost of production decreased by 9% per liter, the norm of animal fat content increased by 26%, and the farmer's income increased by 523 dollars per hectare per year.

C. Implications for policy and practice of agri-food system in Central Asia

The Central Asian countries need a comprehensive strategy that takes into account both the social and environmental aspects of the system in order to develop effective adaptation and mitigation strategies in the region. In 2021, countries faced serious challenges, including record high temperatures, water shortages, crop failures and disruptions in the agri-food supply chain, exacerbated by the COVID-19 pandemic. Agriculture has historically been an important sector that employs a significant portion of the workforce, but in recent years, GDP per capita income has declined due to obstacles to inefficient water use, outdated technologies and limited structural transformation.[123] Changing climatic conditions require rapid adaptation, but structural constraints hinder progress.

[123] Wong Bi Yi, P., & Akhmetov, A. Record high temperatures in Central Asia highlight need for climate action. ESCAP. 2021.
https://www.unescap.org/blog/record-high-temperatures-central-asia-highlight-need-climate-action

In order to reduce risks, the countries of the subregion should focus on improving the management of water resources, crop production and land resources in agriculture. Modernization of water management infrastructure can prevent waste, at the same time it is extremely important to encourage farmers to introduce water-saving technologies, such as drip irrigation, or switch to less water-intensive crops. Improving the fertilizer application system and introducing energy-efficient tillage methods can help reduce greenhouse gas emissions at relatively low costs. In addition, the restoration of degraded lands and the use of methods such as rotational grazing and changing the composition of feed can increase productivity and cultivate organic soils.

For a significant period of time, the Central Asian states were under Soviet rule and adopted similar approaches to governance and policy. Additionally, these countries share many cultural, social, and economic characteristics, which provides the region with an advantage for cooperation and synergy in addressing regional challenges.[124] Since gaining independence, the five countries have largely followed a similar agricultural development pattern, with a focus on the global market economy. Presently, there has been substantial growth in cattle production, representing 58% in Turkmenistan, 84% in Uzbekistan, approximately 60% in Kyrgyzstan and Kazakhstan, within the livestock sector. The agricultural structure in these countries is based on three types: household farming, family farms, and large enterprises.[125]

In order to combat the problem of climate change in the agriculture and livestock sector, Central Asian countries should give priority to policies and practices that promote sustainable intensification. This can be achieved through various approaches such as the improved crop varieties, manure management, introduction of modern technologies, improved irrigation systems, and increased access to resources such as seeds, fertilizers and machinery. Investing in research and development for agriculture and providing training, workshop and extension services to the local farmers can also increase productivity.

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[124] Spoor, M. “Agricultural Restructuring and Trends in Rural Inequalities in Central Asia A Socio-Statistical Survey,” 2005. https://www.semanticscholar.org/paper/Agricultural-Restructuring-and-Trends-in-Rural-in-A-Spoor/a84a551878a31ac10f7e0622bbcf70838a5ea6eb#citing-papers.

[125] Robinson, Sarah. “Livestock in Central Asia: From Rural Subsistence to Engine of Growth?” ResearchGate, May 7, 2020. https://www.researchgate.net/publication/341204278_Livestock_in_Central_Asia_From_rural_subsistence_to_engine_of_growth.

Diversification of agricultural production: Central Asian countries should diversify the types of agricultural production, as well as the resources used in processing, in order to reduce the overuse of certain types of raw materials. One of the best policies can promote the cultivation of high-value crops, horticulture, livestock production, and aquaculture. Providing financial incentives, access to markets, and technical support for smallholder farmers can encourage diversification and value addition in the agri-food system.

Climate change adaptation and resilience: Central Asia is vulnerable to the impacts of climate change, including increased temperatures, changing precipitation patterns, and more frequent extreme weather events. Policies and practices need to prioritize climate-smart agriculture, including the adoption of climate-resilient crops, agroforestry, and conservation agriculture techniques. Supporting farmers with climate information and early warning systems can help them make informed decisions and adapt to changing conditions.

Water management and irrigation: Water scarcity is a significant challenge in Central Asia. Policies should focus on efficient water management strategies, such as the use of drip irrigation, water recycling, and watershed management. Governments should invest in infrastructure development for irrigation systems, including maintenance and repair. Additionally, promoting water-saving practices and raising awareness among farmers about the importance of water conservation can help ensure sustainable water use in agriculture.

Strengthening market linkages and value chains: Improved infrastructure, logistics, and transportation networks are essential for linking farmers to markets in Central Asia. Policies should focus on developing efficient supply chains, cold storage facilities, and processing units to reduce post-harvest losses and increase the value of agricultural products. Supporting farmers' cooperatives and facilitating access to credit and market information can also enhance their bargaining power and profitability.

Sustainable land management: Central Asia faces challenges related to land degradation, desertification, and soil erosion. Policies and practices should prioritize sustainable land management techniques, such as conservation agriculture, agroforestry, and terracing. Promoting land tenure security, implementing land use planning, and supporting land rehabilitation programs can help preserve soil fertility, protect ecosystems, and improve agricultural productivity.

Strengthening rural livelihoods and social safety nets: Central Asian countries should address rural poverty and promote inclusive growth by improving access to credit, rural finance, and agricultural insurance for smallholder farmers. Policies can also focus on enhancing vocational and entrepreneurial skills among rural populations, creating off-farm employment opportunities, and strengthening social safety nets to protect vulnerable communities during crises.

Overall, a comprehensive approach to policy and practice in the agri-food system in Central Asia should prioritize sustainable agriculture, climate resilience, market access, and rural development. Collaboration among governments, international organizations, research institutions, and the private sector is crucial for implementing these policies and practices effectively and achieving a more sustainable and resilient agri-food system in the region.

CHAPTER V

A. Conclusion

Climate change is poised to have a profound negative impact on the agricultural sector and the environment. Its repercussions can manifest as environmental disasters and degradation, particularly affecting water and land resources, which serve as crucial sources of income and livelihoods in rural areas. Central Asia urgently needs to implement effective policies and adaptation measures to mitigate climate change and collaborate to share the risks and consequences. The Aral Sea serves as a stark reminder of the region's plight, as its consequences have not only affected the local population but also the ecosystem itself. As part of the global policy and strategic UN plans, it is imperative for the state to incorporate sustainable agriculture development into the national strategic plan. This entails striving to produce sufficient food to meet the needs of the growing population while preserving the environment, biodiversity, and ensuring the social and economic well-being of all stakeholders.

Agriculture is a major contributor to greenhouse gas emissions, exacerbating global warming due to inefficient use and exploitation of natural resources. In particular, the overuse of pesticides and fertilizers degrades land resources and outdated irrigation systems lead to water loss. The water sector poses challenges not only in terms of technical and infrastructure aspects but also in distribution and management. Inadequate natural resource management further worsens environmental deterioration and accelerates climate change. Furthermore, climate change hastens the melting of glaciers and ice caps in the mountains, which are vital sources of water for Central Asia during the summer.

Online platform GLEAM-i's estimates reveal that improving manure management approaches such as daily spreading and composting can reduce greenhouse gas emissions by approximately 8%. Similarly, enhancing feed quality by diversifying crops like sugar beet and maize can decrease feed intake by 7% and reduce enteric fermentation from cattle. Embracing a range of mitigation and adaptation strategies can contribute to reducing emissions and improving productivity in the face of climate change.

Solving the problems related to climate change in the agricultural sector should be one of the important goals for Central Asia. Failure to act quickly and effectively can have serious consequences for both the environment and the livelihoods of rural communities.

Governments and stakeholders must prioritize sustainable agricultural development and implement effective policies aimed at mitigating the effects of climate change while ensuring food security, environmental conservation, and socio-economic well-being.

To achieve these goals, it is important to introduce innovative and sustainable methods in agriculture, such as promoting organic farming, and investing in climate-resilient crops. In addition, cooperation between Central Asian countries is crucial for the exchange of knowledge, resources, and risks associated with the effects of climate change. Also, international cooperation and support can play a significant role in helping Central Asian countries in their efforts to combat climate change. This support may include technical assistance, financial resources, and capacity-building initiatives for resilience and adaptation measures. By prioritizing sustainable agriculture, reducing greenhouse gas emissions, and protecting natural resources, Central Asia can pave the way for a more sustainable and resilient future.

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