Food and Agriculture Organization of the United Nations

Understanding the role of ruminant systems on greenhouse gas emissions and soil health in selected Central Asian countries

An assessment of ruminant systems and grassland soils in Tajikistan, Kyrgyzstan and Uzbekistan

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Juliana C. Lopes[1], Marta Dondini[1], Munavar Zhumanova[2], Monica Rulli[1] and Alessandra Falcucci[1]

[1] *Food and Agriculture Organization of the United Nations, Animal Production and Health Division, Viale delle Terme di Caracalla, Rome, Italy.*

[2] *Michigan State University, Center for Global Change and Earth Observations, East Lansing, United States.*

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Abbreviations

BAU	Business as usual
C	Carbon
C:N	Carbon to nitrogen ratio
CCI-LC	Climate Change Initiative – Land Cover
CH_4	Methane
CO_2	Carbon dioxide
COP	Conference of the Parties
DRS	Districts of Republican Subordination
ETF	Enhanced Transparency Framework
FAO	Food and Agriculture Organization of the United Nations
FMD	Foot-and-mouth Disease
GAUL	Global Administrative Unit Layers
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographic information system
GLEAM	Global Livestock Environmental Assessment Model
GWP	Global warming potential
HWSD	Harmonized World Soil Database
IPCC	Intergovernmental Panel on Climate Change
LC	Land cover
LCA	Life Cycle Assessment
LCCS	Land Cover Classification System
LULUCF	Land Use, Land Use Change and Forestry
MMS	Manure Management Systems
MPG	Modalities, Procedure and Guidelines
MRV	Measuring, Reporting and Verification
N_2O	Nitrous oxide
NAMAs	Nationally Appropriate Mitigation Action
NDC	Nationally determined contributions
PPR	Pestes des Petits Ruminants
SLCP	Short-lived climate pollutants
SOC	Soil organic carbon
UNFCCC	United Nations Framework Convention on Climate Change

Executive summary

NATIONAL CIRCUMSTANCES RELATED TO CLIMATE AND RUMINANT SECTOR

Kyrgyzstan, Tajikistan and Uzbekistan are Central Asian states with a rich heritage of nomadic civilization characterized by a climate with low rainfall and extreme temperatures and a landscape of mountains, deserts and steppes. Pastures and grasslands constitute the principal land use and are well suited to extensive ruminant production, carrying approximately 16.8 million cattle, 6.6 million goats and 26.8 million sheep.

Following the breakup of the Soviet Union in the early 90's, these countries became independent and moved from a centrally-planned economic system to a market-oriented economy. The ruminant sector was directly affected by the new market and political dynamics, resulting in drastic reduction of the ruminant stock due to the elimination of subsidies, increasing agriculture input prices, and farm ownership changes. In 1997, the cattle, goat and sheep population reached their lowest stocks, and cattle and goat stocks fell by 8 and 18 percent, respectively, while the sheep stocks were reduced by nearly 40 percent. Currently, the ruminant stock has re-established itself and is greater than ever, with cattle, goat and sheep stocks 118, 214 and 28 percent greater than the stocks in 1992. The increase in animal numbers and changes in the ruminant species composition have contributed to the high levels of overgrazing and consequently, to land degradation and low levels of livestock productivity.

Like many other economies in transition, Kyrgyzstan, Tajikistan and Uzbekistan face the dual challenge of promoting development and reducing greenhouse gas (GHG) emissions, and ruminant systems are central for achieving both goals.

Given the important economic, nutritional and environmental roles that ruminant systems play in Central Asia, Kyrgyzstan, Tajikistan and Uzbekistan were selected as country beneficiaries of the project "Identifying low carbon and climate resilient pathways for the ruminant sector in the selected countries of Central Asia," led by the Food and Agriculture Organization of the United Nations (FAO), aimed at strengthening the capacity of national stakeholders to design large-scale climate change relevant interventions in the ruminant sector by enhancing the understanding of the role of ruminants and grasslands in GHG emissions and soil organic carbon sequestration.

KEY FINDINGS

This study found that in 2018, ruminant systems in Kyrgyzstan, Tajikistan and Uzbekistan emitted 58.2 million tonnes of CO_2 eq. Within this, enteric methane is the major source of emissions representing about 72 percent of the total ruminant GHG emissions. The study also found a wide variability in emission intensities (kg of GHG emissions per kg of protein) between and within countries. This wide variability is explained by the production gaps across and within production systems and feeding practices adopted by each production system. Based on the information generated by this study, there are opportunities and potential to reduce both emission intensity and absolute GHG emissions, while increasing ruminant productivity.

This study found that soil carbon stocks are low in all three countries, with mean country values from 34 tonnes C/ha in Uzbekistan, 46 tonnes C/ha in Tajikistan to 57 tonnes C/ha in Kyrgyzstan. Low carbon stocks in these regions are due to the natural conditions prone to desertification processes and are associated with climatic features – extreme seasonal temperatures and scarce precipitation. Within each country, environmental conditions, such as topography and microclimate, affected the distribution of soil carbon stocks.

This study found that enteric methane and manure management are the predominant sources of emissions from cattle systems; however, the present study also showed that regions with high GHG emissions from the cattle systems also had the highest soil carbon stocks. This is mainly due to the high apportion of carbon into the soil from manure and organic amendments. Thus, in these regions, tailored practices could likely reduce GHG emissions through practices that can increase organic carbon storage.

WAY FORWARD

Moving from Tier 1 to Tier 2 based inventories is a critical step towards accounting for emissions and mitigation actions from the livestock sector, as Tier 2 methods portray a more accurate picture of a livestock system (both animal and grasslands) and its level of productivity and can capture the effects of improved management practices and technologies on emissions over time.

Improved systems for collecting and sharing data and properly characterizing the production systems would benefit both climate and livestock stakeholders. In the future, special attention should be given to improve the national livestock statistics, reconsider the definition of ruminant systems based on current practices and spatial allocation, collect and create a database with soil, herd and feed parameters and link data collection with spatially explicit technologies.

Strengthening measuring, reporting and verification (MRV) systems through the adoption of country-specific emission factors and use of GIS technologies can support the design of more realistic climate targets and be a useful tool for tracking progress towards meeting those targets. Furthermore, the use of advanced inventories demonstrates greater ambition and commitment towards resolving the climate crisis and can facilitate access to climate finance.

Резюме

НАЦИОНАЛЬНЫЕ УСЛОВИЯ, СВЯЗАННЫЕ С КЛИМАТОМ И СЕКТОРОМ ЖИВОТНОВОДСТВА

Центральноазиатские страны-Кыргызстан, Таджикистан и Узбекистан — государства с богатым наследием кочевой цивилизации. В сочетании с горным ландшафтом, пустынь и степей территория имеет резко континентальный климат с малым количеством осадков и перепадами температуры. Использование пастбищных угодий для экстенсивного животноводства является основным видом землепользования, где выпасается около 16,8 млн. голов крупного рогатого скота, 26,8 млн. овец и 6,6 млн. коз.

В начале 90-х годов в результате распада Советского Союза страны стали независимыми и перешли от централизованно-плановой системы к рыночно-ориентированной экономике. Рыночная экономика и политическая динамика оказали непосредственное влияние на сектор животноводства, в частности на жвачных животных. В связи с прекращением государственных субсидий, ростом цен на сельскохозяйственную продукцию и изменением форм собственности в фермерских хозяйствах произошло резкое сокращение поголовья жвачных животных. К 1997 году поголовье крупного рогатого скота, овец и коз достигло самого низкого уровня, в частности поголовье КРС уменьшилось на 8 восемь процентов, коз на 18 процентов, тогда как поголовье овец сократилось почти на 40 процентов. В настоящее время численность жвачных животных восстановилось и наблюдается динамика роста поголовья. По сравнению с 1992 годом поголовье крупного рогатого скота выросло на 118 процентов, овец на 28 процентов и коз на 214 процентов, что привело к чрезмерному выпасу пастбищ. Более того, изменение видового состава и увеличение размеров стада с низким уровнем продуктивности привели к деградации земель.

Как и многие другие страны с переходной экономикой, Кыргызстан, Таджикистан и Узбекистан сталкиваются с двойной задачей: способствовать экономическому развитию и одновременно сокращению выбросов парниковых газов (ПГ). В этом отношении системы содержания жвачных животных играют центральную роль в достижении обеих целей. Учитывая важную экономическую, продовольственную и экологическую роль разведения жвачных животных для стран Центральной Азии, Кыргызстан, Таджикистан и Узбекистан были выбраны в качестве стран-бенефициаров проекта “Определение низкоуглеродных и климатически устойчивых путей для сектора разведения жвачных животных в отдельных странах Центральной Азии”. Проект возглавляет Продовольственная и сельскохозяйственная организация ООН, с целью укрепления потенциала национальных заинтересованных сторон в области разработки крупномасштабных мероприятий, связанных с изменением климата в секторе разведения жвачных животных, путем улучшения понимания роли жвачных животных и пастбищных угодий в выбросах ПГ и улавливания органического углерода почвой.

КЛЮЧЕВЫЕ ВЫВОДЫ

Данное исследование показало, что в 2018 году в Кыргызстане, Таджикистане и Узбекистане от систем разведения жвачных животных выброс составил 58,2 млн. тонн CO_2-экв. Основным источником выбросов является энтеральный метан, на долю которого приходится около 72 процентов от общего объема выбросов ПГ жвачными животными. Также была выявлена широкая вариабельность интенсивности выбросов (кг выбросов ПГ / кг белка) между и внутри государств. Эта широкая вариабельность объясняется производственными пробелами между и внутри производственных систем, а также практикой кормления, принятой в каждой производственной системе разведения.

На основе полученной информации можно сделать вывод, что имеются возможности и потенциал для сокращения как интенсивности выбросов, так и абсолютных выбросов ПГ при одновременном увеличении продуктивности жвачных животных. Также стало известно, что запасы углерода в почве являются низкими во всех трех странах, при этом средние значения по странам варьируются от 34 тонн C/га в Узбекистане, 46 тонн C/га в Таджикистане, до 57 тонн C/га в Кыргызстане. Низкие запасы углерода в этих странах обусловлены природными условиями, предрасположенными к процессам опустынивания, и связаны с климатическими особенностями –экстремальными сезонными температурами и малыми осадками. Экологические условия, такие как рельеф и микроклимат, в пределах каждой страны влияют на распределение запасов углерода в почве.

К тому же исследование показало, что энтеральный метан и использование навоза являются преобладающими источниками выбросов в системах разведения крупного рогатого скота. Хотя регионы с высокими выбросами ПГ от систем разведения крупного рогатого скота имеют самые высокие запасы почвенного углерода. Это объясняется главным образом высоким распределением углерода в почве от навоза и органических удобрений. Таким образом, применение индивидуальных подходов может сократить выбросы ПГ за счет практик земледелия, которые направлены на увеличение накоплений органического углерода в этих регионах.

ДАЛЬНЕЙШИЕ ДЕЙСТВИЯ

Переход инвентаризации с Уровня 1 на Уровень 2 является важным шагом на пути к учету выбросов и действий по смягчению последствий от сектора животноводства. Поскольку методы Уровня 2 отображают более полноценную картину системы животноводства (как животных, так и пастбищ) и ее уровень продуктивности, а также могут охватить эффекты от усовершенствованных практик и технологий управления на выбросы с течением времени.

Усовершенствованные системы сбора и обмена данных, а также надлежащая характеристика производственных систем буд полезны заинтересованным сторонам, занимающимся вопросами климата и животноводства. В дальнейшем следует уделять особое внимание улучшению национальной статистики в области животноводства, пересмотру определения систем разведения жвачных животных на основе существующей практики и пространственного распределения, сбору и созданию базы данных с параметрами почвы, стада и кормов, а также увязке сбора данных с пространственно эксплицитными технологиями.

Укрепление систем измерения, отчетности и проверки (ИОП) путем принятия коэффициентов выбросов для конкретных стран и использования ГИС технологий будет содействовать разработке более реалистичных климатических целей, которая в свою очередь будет полезным инструментом для наблюдения за достижением этих целей. Кроме того, использование продвинутых инвентаризаций демонстрирует большие амбиции и ответственность за решение проблемы климатического кризиса и может облегчить финансирование деятельности в рамках борьбы с изменением климата.

Данный проект является первым шагом на пути к пониманию роли жвачных животных с помощью передовых методов расчета выбросов ПГ и служит основой для того, чтобы эти государства могли взять на себя осуществление более масштабных климатических инвестиционных проектов и стимулировать климатические меры на основе устойчивого развития животноводства.

1. National circumstances related to climate and ruminant sector

Kyrgyzstan, Tajikistan and Uzbekistan are Central Asian states with a rich heritage of nomadic civilization characterized by a climate with low rainfall and extreme temperatures and a landscape of mountains, deserts and steppes. Pastures and grasslands constitute the principal land use, ranging from 82 to 87 percent of the total agricultural area, and are well suited to extensive ruminant production, carrying approximately 16.8 million cattle, 6.6 million goats and 26.8 million sheep (FAO, 2018).

Before independence in 1991, Kyrgyzstan, Tajikistan and Uzbekistan were part of the Soviet Union. The organization of employment, production and activities, including the agriculture sector, were organized following the principals of a centrally planned economy. Agricultural production was organized mainly in the large collective and state enterprises, and farming decisions on crop choice, cropland area, number of livestock stocks and grazing mobility were made by a central authority. In turn, the government supplied the necessary inputs (fertilizer, pesticides, seeds, machinery, feed, etc.) and technical support to attain the targeted agricultural production outputs (Suleimenov and Oram, 2000).

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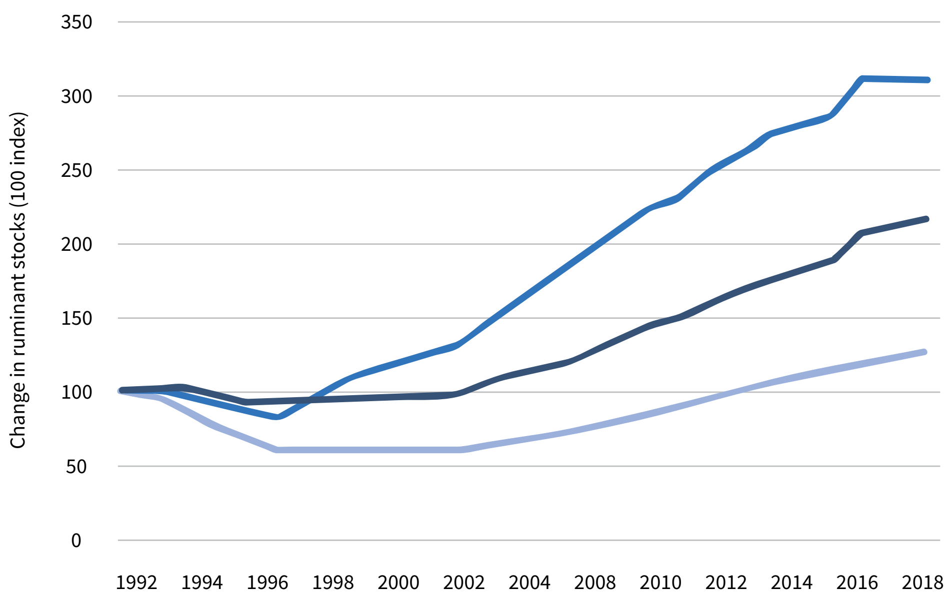
Figure 1.1 Changes in ruminant stocks in Kyrgyzstan, Tajikistan and Uzbekistan after independence



Source: FAO. 2018.

In the years after the independence, ruminant stocks in these countries rapidly decreased as a consequence of the elimination of subsidies, higher agriculture input prices, job losses and production system and market changes, moving from state-owned or controlled enterprises to private farms and from a planned, centred economy to a market-based one (Broka *et al*., 2016a; Squires, 2012; World Bank, 2007; Lerman and Sedik, 2009, 2018). In 1997, the cattle, goat and sheep population reached their lowest stocks, and cattle and goat stocks fell by 8 and 18 percent, respectively, while the sheep stocks were reduced by nearly 40 percent. Currently, the ruminant stock has re-established itself and is greater than ever, with cattle, goat and sheep stocks 118, 214 and 28 percent greater than the stocks in 1992.

The composition of the ruminant stocks has also changed in response to the economic and political changes (Lerman and Sedik, 2018; Mogilevskii *et al*., 2017; Tilekeyev *et al*., 2017). In particular, the goat population has remarkably risen and is three times greater than what it used to be before independence. As sheep were initially used for trading during the first post-independence years, poor livestock farmers opted for restocking the herds with goats instead. Moreover, farmers opted for goats over sheep because of their greater prolificacy, lower costs, adaptability to graze mountainous pastures, and easy management (Kerven, McGregor and Toigonbaev, 2009; Robinson, Safaraliev and Muzofirshoev, 2010).

GRAZING AND SOIL CARBON STOCKS

The increased grazing pressure due to the expansion of the ruminant herd and changes in species composition[1] combined with reduced seasonal mobility, lack of investments and changes in pasture tenure regulations have altered the relationship between ruminants and the natural resource base.

There is a common perception among stakeholders that pastures are degraded and that pasture productivity is declining due to increasing livestock numbers (Robinson, 2016); further, degradation of the grasslands in Central Asia is estimated to cost about USD 4.6 billion per year (Mirzabaev *et al.*, 2015). Besides reducing the productivity of livestock systems and directly affecting rural livelihoods, the unsustainable management of the grasslands (overstocking and overgrazing) also reduces the carbon sequestration potential from the grasslands in the region. These Central Asian nations, combined, have 34.2 million hectares of natural grasslands that, if restored and well managed, could offer a significant opportunity to sequester carbon and make a unique contribution to mitigation and adaptation to climate change, as well as to improve land and ecosystem health and resilience.

GHG EMISSIONS AND INTERNATIONAL CLIMATE COMMITMENTS

Like many other economies in transition, Kyrgyzstan, Tajikistan and Uzbekistan face the dual challenge of promoting development and reducing greenhouse gas (GHG) emissions, and ruminant systems can play a central role in achieving both goals.

Kyrgyzstan emitted about 13 046 Gg CO_2 eq. in 2010, with the agriculture sector contributing to 33 percent of the national GHG inventory (National Communication of the K.R., 2017). Within agriculture emissions, livestock emissions related to enteric fermentation and manure management represented 59.3 and 3.1 percent, respectively, of the total sector's emissions (Figure 1.a). Kyrgyzstan's Nationally Determined Contribution (NDC) proposes to unconditionally reduce national GHG emissions from 11.5 to 13.8 percent below business as usual (BAU) by the year 2030. If support from the international community is provided, the country proposes to reduce emissions by 29.0 to 30.9 percent below the BAU in 2030. Although the agriculture sector is one of the main sources of livelihoods, as well as one of the most vulnerable sectors of the economy, no adaptation or mitigation actions have been identified for the sector in the country's NDC.

Tajikistan emitted 6.1 Gg CO_2 eq. (including net emissions/removals with land use, land-use change, and forestry, LULUCF), and the agriculture sector accounted for the majority of these emissions (70 percent) in 2010 (National Communication of the R.T., 2014). Domestic emissions from livestock corresponded to almost half of the sector's emissions within agriculture emissions (Figure 1.b). In its NDC, Tajikistan proposed to reduce total GHG emissions from 10 to 20 percent by 2030 compared to 1990 baseline emissions, but no mitigation targets or actions focusing on agriculture and livestock were included.

[1] Due to different grazing behaviour.

Uzbekistan's GHG emissions in 2012 were about 198 869 Gg CO_2 eq. The agriculture sector represents the second largest share of emissions (10 percent) after the energy sector (National Communication of the R.U., 2016). Within agriculture emissions, livestock-related emissions account for almost 60 percent, with enteric fermentation and manure management representing 56 and 6 percent of the sector's emissions, respectively (Figure 1.2). As part of Uzbekistan's commitment to the Paris Agreement, the country proposed to decrease GHG emissions per unit of GDP (gross domestic product) by 10 percent by 2030 and included adaptation measures focusing on improving pasture productivity and fodder production in desert and piedmont areas.

Given the important economic, nutritional and environmental roles that ruminant systems play in Central Asia, Kyrgyzstan, Tajikistan and Uzbekistan were selected as country beneficiaries of the project "Identifying low carbon and climate resilient pathways for the ruminant sector in the selected countries of Central Asia" which was led by the Food and Agriculture Organization of the United Nations (FAO). The project aimed to strengthen the capacities of national stakeholders to design large-scale climate change relevant interventions in the ruminant sector. This would be achieved by (i) enhancing understanding of the roles of ruminant systems and grasslands on GHG emissions through advanced GHG accounting methods and (ii) catalysing climate action through sustainable livestock development.

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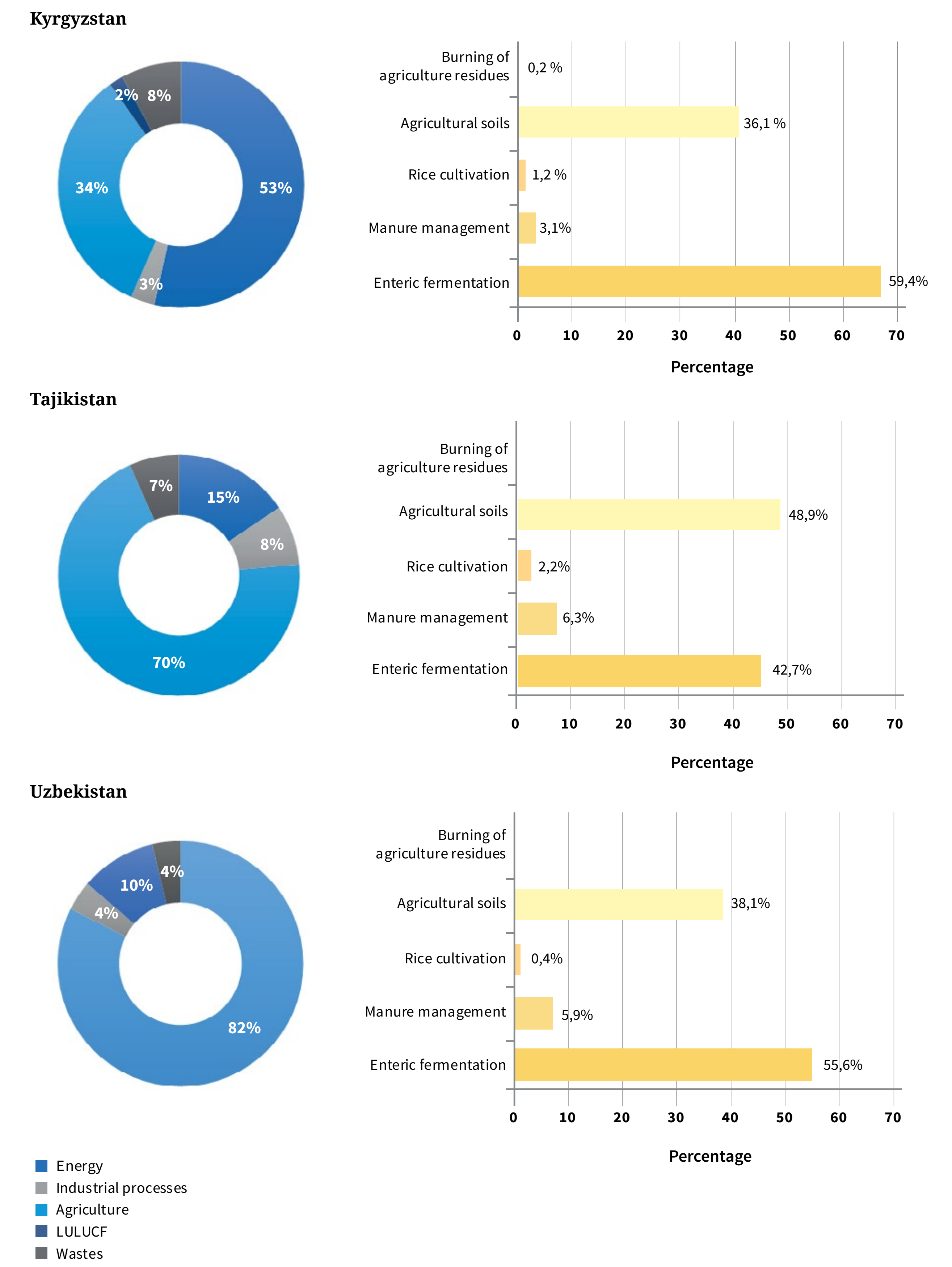
Figure 1.2 GHG emissions contribution by sector (blue) and within the agriculture sector (yellow) from Kyrgyzstan, Tajikistan and Uzbekistan



Source: National Communication of the K.R. 2017. *Third National Communication of the Kyrgyz Republic under The U.N. Framework Convention on Climate Change.*

2. Materials and methods

To meet the needs of this study, the ruminant production systems in the Global Livestock Environmental Assessment Model[2] (GLEAM, Box 2.1) were further refined to reflect the specificities of the ruminant production systems in Central Asia. Data on cattle, sheep and goat populations, herd parameters, feeding systems and manure management were updated with the most recent and disaggregated information available. Additionally, a soil organic carbon (SOC) module based on RothC, a soil process-based model, was incorporated into GLEAM to estimate carbon sequestration potential under grasslands and the inputs needed to maximize soil carbon sequestration (more details at Box 2.2).

A team of national researchers from the University of Central Asia, in collaboration with FAO, carried out a desk review on production systems, feed and nutrition, animal health, animal genetics and breeding practices applicable according to the local context. Later, a series of consultation workshops were held in the project-participating countries during September and October 2019, gathering 96 stakeholders from academia, government and farming associations.

During the workshops, the proposed production systems, data inputs and modelling assumptions were presented, reviewed and corrected or validated by the group of national stakeholders. After the workshops, the data and information previously collected were consolidated and combined with the most up to date official ruminant population data and integrated into GLEAM.

Box 2.1 Modelling GHG emissions from ruminant production systems in Central Asia

The Global Livestock Environmental Assessment Model (GLEAM; Gerber *et al.*, 2013) is a spatially explicit model of livestock production systems that simulates the biophysical processes and activities along livestock supply chains, using a life cycle assessment approach (LCA). The model captures the environmental impacts of each stage, offering a comprehensive and disaggregated picture of livestock production and its use of natural resources.

The model estimates both direct (enteric fermentation, manure management and on-farm energy use) and indirect (feed production, processing and transportation, processing and post-farm transport of livestock commodities), following the IPCC Tier 2 methodology.

GLEAM works at a resolution level of 1 km_2, which enables the model to incorporate and represent the heterogeneity in emissions, emission reductions and production responses at different spatial levels.

Emissions and emission intensities are reported as CO_2 equivalent emissions, based on 100-year global warming potential (GWP_{100}) conversion factors as reported by the IPCC in its 5th Assessment Report (AR5; N_2O GWP_{100} 298; CH_4 GWP_{100} 34).

[2] GLEAM. http://www.fao.org/gleam/en/

Box 2.2 Assessing the baseline soil carbon stocks of grasslands in Central Asia

RothC is a simple, process-based model that includes carbon only. It simulates the turnover of organic carbon in non-waterlogged topsoil (Coleman and Jenkinson, 1996) using a monthly time step to calculate total SOC. The model has been widely tested and used at the plot, field, regional and global scales, using data from long-term field experiments throughout the world.

The data required to run the model are: monthly rainfall and evaporation or potential evapotranspiration (mm), monthly air temperature (°C), clay content (%), an estimate of the decomposability of the incoming plant material, monthly soil cover (whether the soil is bare or vegetated), monthly input of plant residues (tonnes C/ha) and monthly input of farmyard manure (tonnes C/ha), if any.

RothC uses a pool type approach, describing SOC as pools of inert organic matter, humus, microbial biomass, resistant plant material and decomposable plant material. During the decomposition process, material is exchanged between the SOC pools according to first order rate equations. These equations are characterized by a specific rate constant for each pool and are modified according to rate modifiers which are dependent on the temperature, moisture, and crop cover of the soil. The decomposition process results in gaseous losses of carbon dioxide (CO_2).

The Harmonized World Soil Database (HWSD) version 1.2 was used to provide initial soil conditions in the model (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2012). The HWSD provides soil data to a depth of one meter at a resolution of 30 arc s (approximately 1 km), for the dominant soil types in each grid cell. The soil properties used from this database to drive RothC were organic carbon content, bulk density, and clay faction. The HWSD also provides the percentage of grid cell area covered by each soil type. The RothC model is run for each dominant soil type in each grid cell at a soil depth of 30 cm and the output area-weighted by the percentage cover in each grid cell to calculate its mean response.

RothC requires monthly precipitation and air temperature data to determine temperature-based rate modifiers for various soil processes. The meteorological driving data were taken from Harris *et al.* (2014).

The CCI-LC project delivers consistent global land cover maps at 300 m spatial resolution on an annual basis covering the period from 1992 to 2015. The L.C. map from the year 2015 at a global scale was used to identify grassland extent and distribution in the three countries. This geospatial database provides 23 classes and is defined using the Land Cover Classification System (LCCS) developed by FAO. For the present study, four land use categories have been selected to represent grassland: 1) mosaic herbaceous cover (>50%) / tree and shrub (<50%), 2) shrubland, 3) grassland and 4) sparse vegetation (tree, shrub, herbaceous cover) (<15%).

The Global Administrative Unit Layers (GAUL) database was used to analyse results by regions. Carbon input from plant residues and manure were also used as input to the model. They were both derived from GLEAM, with plant residues calculated as the difference of aboveground biomass minus animal intake. Carbon input from manure was derived from the nitrogen available estimated by the GLEAM manure module. The nitrogen available was converted to carbon by applying a C:N ratio for manure of 24.7.

The RothC model was run for 30 years to 2018, assuming steady-state soil conditions at the start of the simulation. This assumption was necessary to partition the starting soil carbon into the five conceptual carbon pools.

3. Kyrgyzstan

PRODUCTION SYSTEMS

Livestock is a key agricultural commodity for most farmers providing a source of income and social safety net for low-income households (IFAD, 2013; IFAD, 2018). The livestock sector is economically significant and sustains the livelihoods of 428 000 smallholder farms that combined own more than 90 percent of ruminant stocks and are responsible for 87 percent of total ruminant output (NSC of the K.R., 2019). With 1.8 million head of cattle stocks (NSC of the K.R., 2019), cattle production in Kyrgyzstan can be divided into three main systems: specialized dairy, specialized beef and dual-purpose. The dual-purpose system is the predominant production system, with 92 percent of the total cattle herd and is carried out in virtually all regions. Specialized beef systems represent 5 percent of the cattle herd and can be found in some provinces from the Zhalal-Abad, Naryn, and Chuy. In comparison, specialized dairy systems account for a minor part of the cattle herd (3 percent) and are found mainly in the Chuy region.

The small ruminant herd is composed of 0.14 million goats and 1.1 million sheep and found in all Kyrgyzstan regions (NSC of the K.R., 2019). Sheep farming is a traditional practice, one of the most important agriculture branches in the country and is particularly important for meat (79 percent) and wool production (9 percent). Goat breeding is the preferred livestock species of poor rural households; given its prolificacy, adaptability to harsh environments and lower feeding requirements, it represents 12 percent of the small ruminant herd. Wool production was an important activity during the Soviet regime given its demand for animal fibers and skins (ICARDA, 2003). During the Soviet period, several breeding programs were implemented to improve animal productivity and fiber quality of sheep and goats, but these programs were interrupted after the Soviet collapse (Iñiguez *et al.*, 2014;

ICARDA, 2003). In the last decades, sheep production has been gradually reoriented from wool production towards meat rearing (Tilekeyev *et al.*, 2017), resulting in the boost of the fat-tailed sheep population (Deniskova *et al.*, 2019; Lushikhina, 2013). The reasons for such a trend include the depression of the world wool market and the rising price for mutton, which is also the key food component of the Kyrgyz diet (Schillhorn van Veen, 1995; Farrington, 2005; Kerven, McGregor and Toigonbaev, 2011).

Ruminant systems are based on pasture grazing, and therefore, subjected to the effects of seasonality with most households suffering from forage shortages during winter. Animals are moved to graze the spring and summer pastures above the villages from mid-April until the first snowfall and migrate back to the villages in mid-October to graze the near-village pastures and receive concentrate supplementation until spring pastures regrowth (Zhumanova *et al.*, 2016; Azarov *et al.*, 2020). Distances, seasonal grazing movements and grazing areas used by individual herders have drastically decreased after the Soviet collapse leading to overgrazing and pasture degradation, especially of near-village pastures (Robinson, 2016).

Sub-nutrition and several infectious diseases such as foot-and-mouth disease (FMD), brucellosis, echinococcus, anthrax disease, rabies and sheep and goat pox are widespread which explains the high mortality rates, low level of productivity and poor reproductive performance (IFAD, 2013, 2016, 2018; JICA, 2013). Kyrgyzstan has no inventory of manure storage systems, and records of manure management are not maintained, but it is known that most of the manure is deposited on pastures during summer and the manure collected during winter is used as organic fertilizer and for heating and cooking by rural households (Zhumanova, 2019).

GHG EMISSIONS AND EMISSION INTENSITIES

Ruminant systems in Kyrgyzstan emitted about 4.1 million tonnes CO_2 eq. in 2018, from which 84 percent was emitted by cattle systems (meat, dairy and dual-purpose), and 16 percent was emitted by small ruminant systems (sheep reared for meat, sheep reared for wool, and goats).

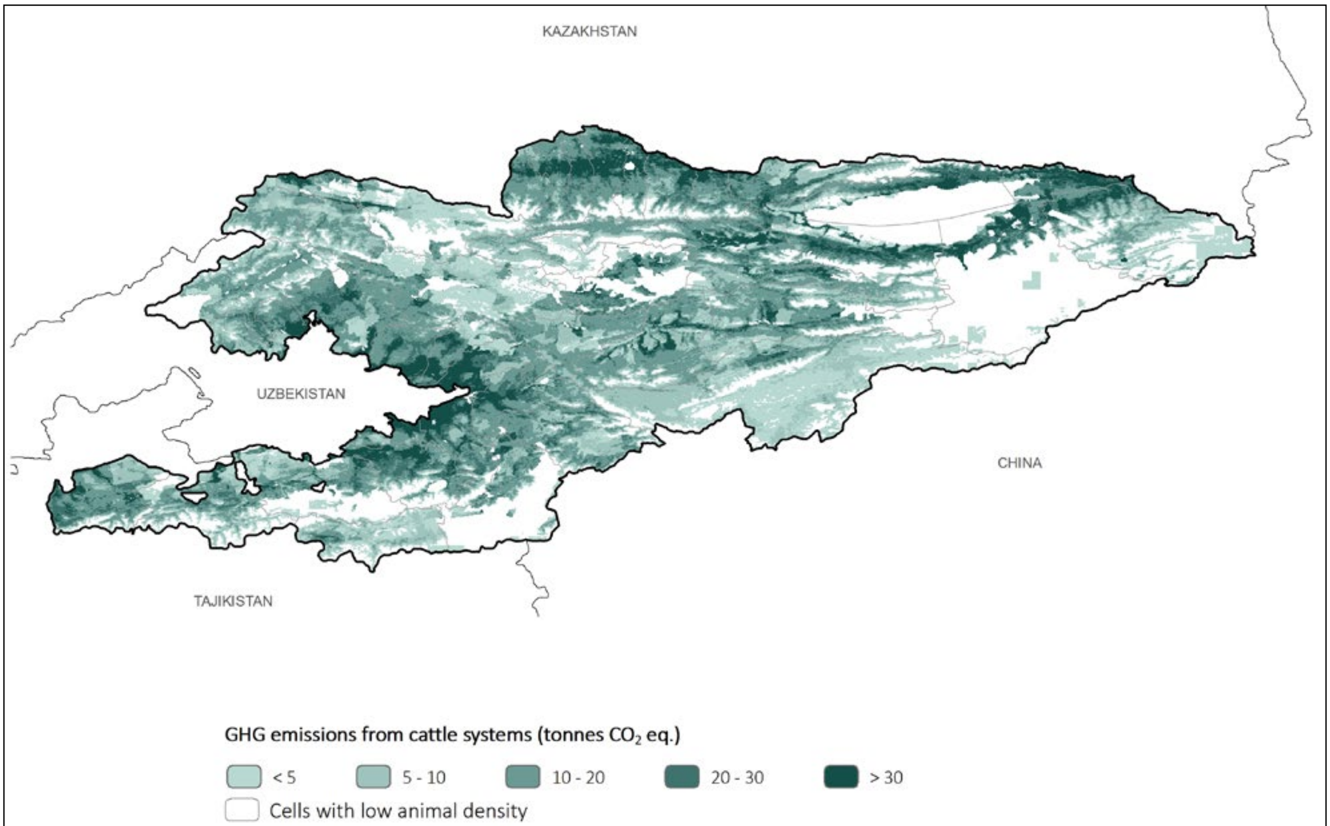
Total GHG emissions distribution from cattle systems (Map 3.1) across oblasts (first level of administrative division) is closely related to the distribution of cattle, with the greatest part of the emissions concentrated in the Issyk-Kul and Osh, Zhalal-Abad, and Batken oblasts.

Within the cattle systems, dual-purpose systems, which produce 95 percent of the national ruminant protein supply (milk and meat), are responsible for 92 percent (3.1 million tonnes CO_2 eq.) of the total GHG emissions, while specialized beef and dairy cattle herds contribute to the remaining 8 percent (0.19 and 0.11 million tonnes CO_2 eq., respectively). Cattle systems present similar emissions profiles, with enteric methane as the predominant source of emission across all systems, followed by emissions related to manure management and feed production (Figure 3.1; Figure 3.3).

The pasture availability and quality vary throughout the year in response to changes in sunlight and temperature. To cope with the reduced availability of fresh grasses during winter, farmers adopt specific feeding strategies, such as the supplementation of conserved forages, supplemented by grains and different types of by-products, in order to meet the animals' nutritional requirements during this period.

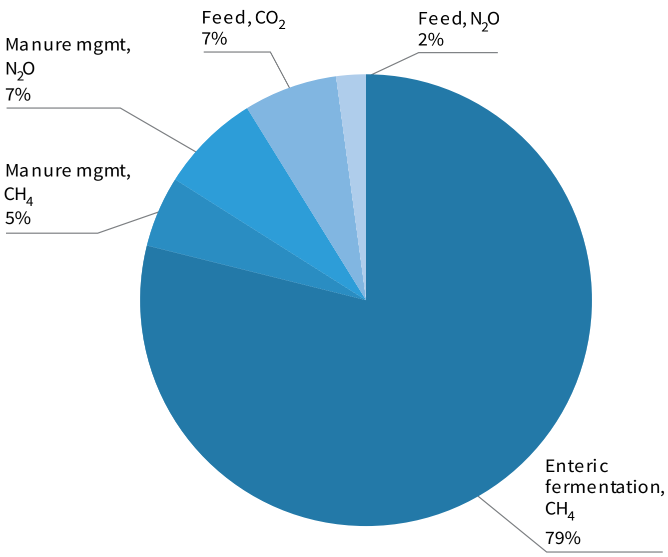
Data related to dietary changes by season were available and enabled the modelling of seasonality effects on GHG emissions from ruminant systems. During the summer, animals are allowed to graze summer pastures, and most of the diet is composed of fresh grass. In contrast, animals are confined nearby the household during winter months and fed conserved forages and concentrates. The study found that 56 percent of the total GHG emissions were attributed to winter

Map 3.1 Regional distribution of total GHG emissions from cattle systems in Kyrgyzstan



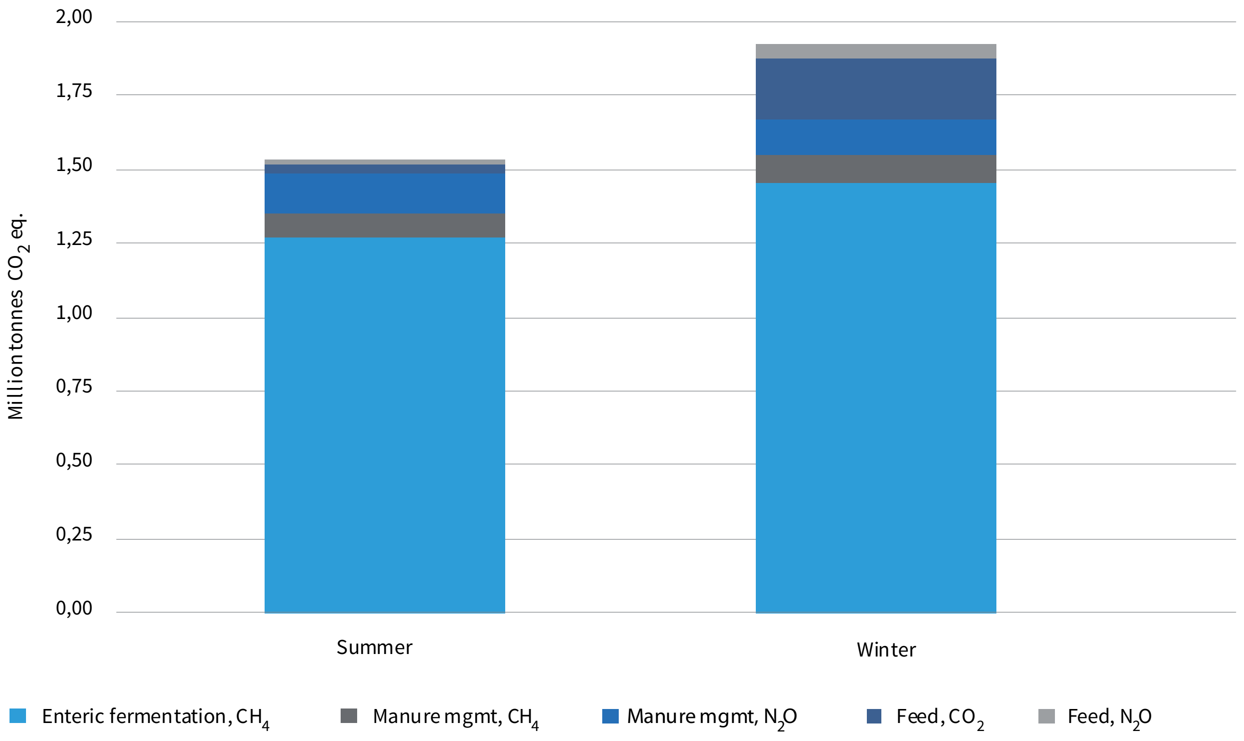
Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

Figure 3.1 Share of total emissions by emission source from cattle systems in Kyrgyzstan



Source: FAO. 2020.

Figure 3.2 Absolute emissions by cattle systems and source by season in Kyrgyzstan



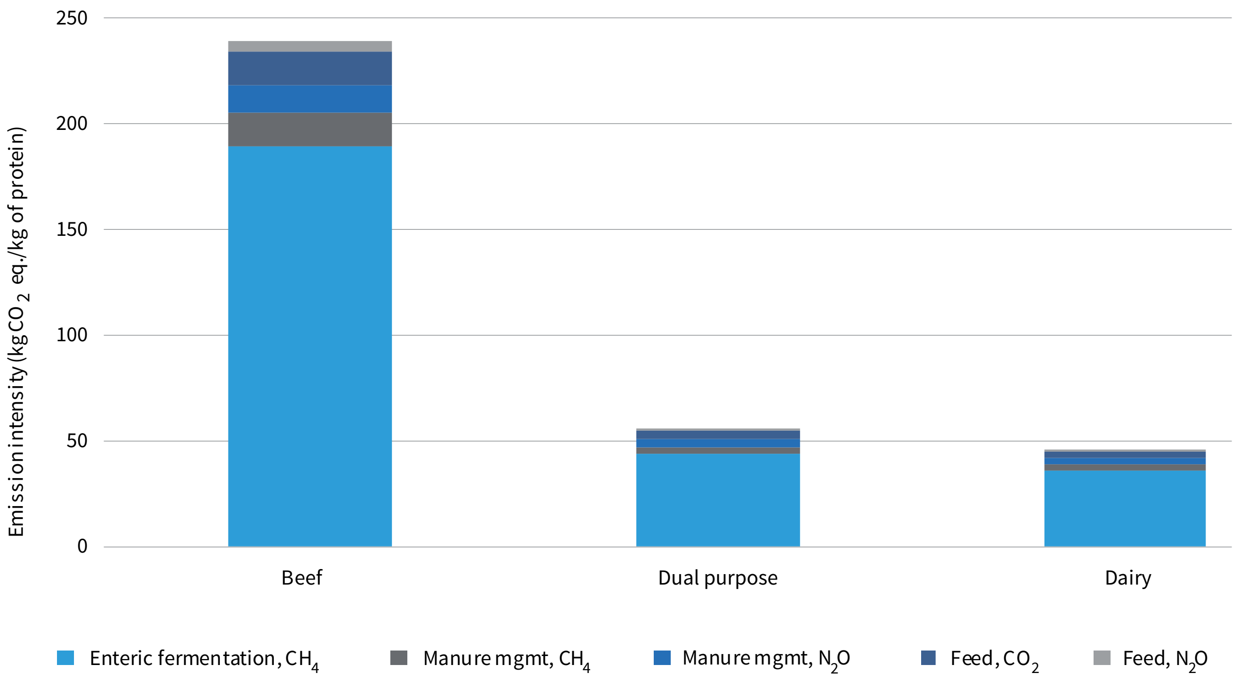
Source: FAO. 2020.

season, while the remaining 44 percent were attributed to the summer season. Although in terms of absolute emissions, enteric methane emissions were 14 percent higher during winter, it is interesting to note that the share of emissions related to enteric fermentation were slightly reduced during this period, contributing 76 percent of the total emissions during winter, compared to 83 percent of the total cattle GHG emissions during summer. This shift is explained by the accentuated increase in emissions related to feed production and processing (CO_2 and N_2O) resulting from the higher proportion of concentrate fed during winter (Figure 3.2). Unfortunately, information related to manure management practices by season were not available for this assessment, but it is expected that a higher share of the manure is collected, dry stored and later used for fuel; therefore, the contribution to GHG emissions related to manure management would also change throughout the year.

At national level, the emission intensity per unit of protein produced by cattle systems is on average 58 kg CO_2 eq./kg of protein (milk and meat); the highest values were estimated for beef systems and the lowest in dairy systems (Figure 3.3). Average emissions ranged from 216 to 249 kg CO_2 eq./kg of protein for beef systems (Map 3.2) and 30 to 118 kg CO_2 eq./kg of protein for dual-purpose systems (Map 3.3), while for dairy systems, emission intensity ranged from 25 to 230 kg CO_2 eq./kg of protein (Map 3.4). This wide variation in emission intensity within and between systems is closely related to the level of productivity obtained in each oblast and the feeding and management practices adopted by each system.

Within small ruminant systems, sheep intended for meat production are responsible for 79 percent (526.1 thousand tonnes CO_2 eq.) of the total small ruminant emissions, followed by goats that emitted 12 percent (80.5 thousand tonnes CO_2 eq.) and sheep reared for wool production, which were responsible for the remaining 9 percent (61.9 thousand tonnes CO_2 eq.) of the total emissions.

Figure 3.3. Emission intensity by cattle systems per year in Kyrgyzstan



Source: FAO. 2020.

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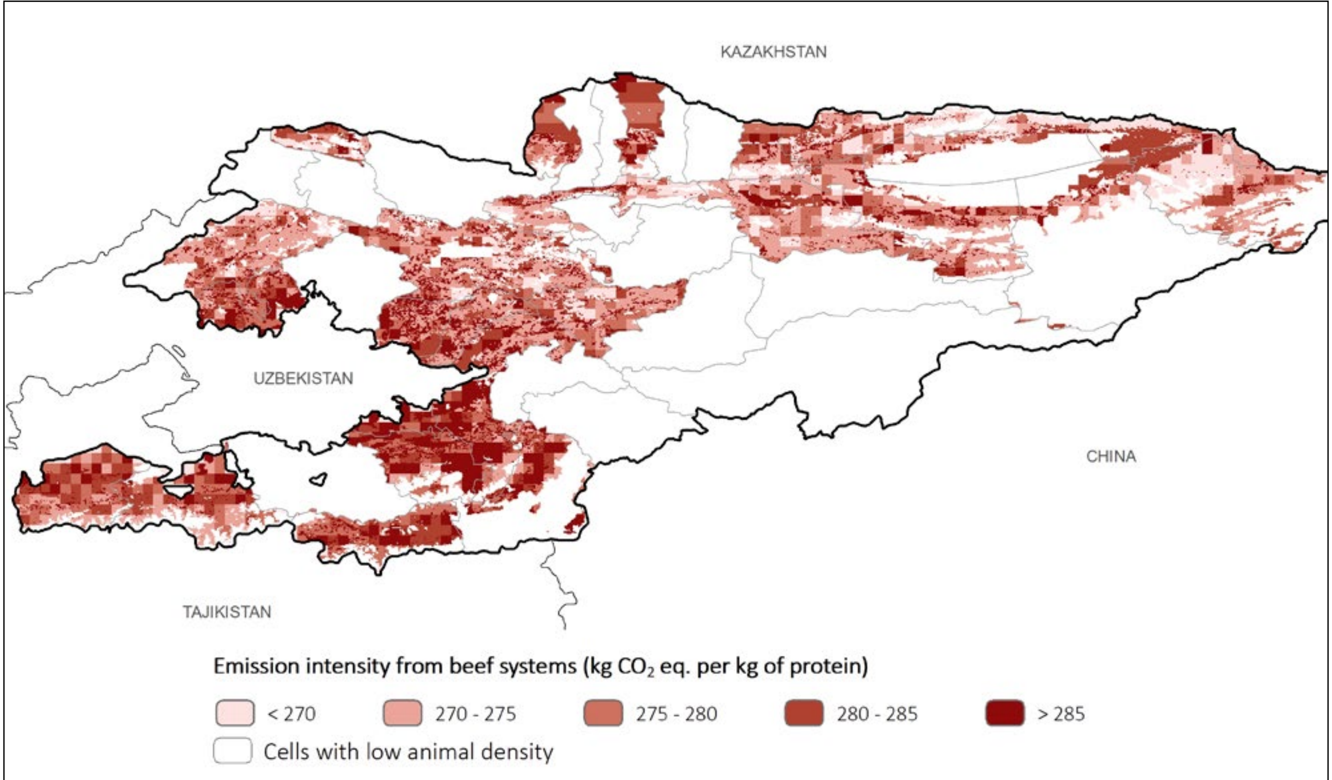
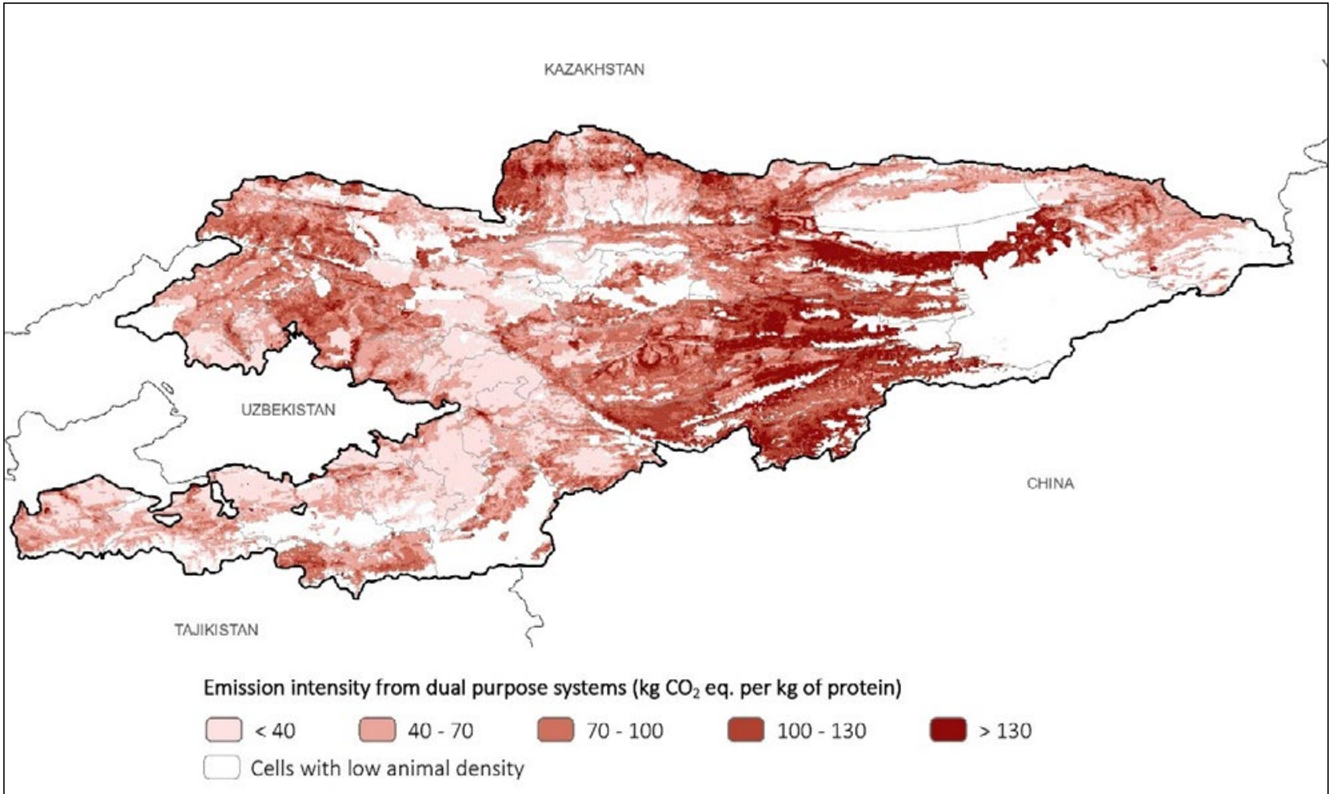
Map 3.2 Regional distribution of emission intensity from beef cattle systems in Kyrgyzstan



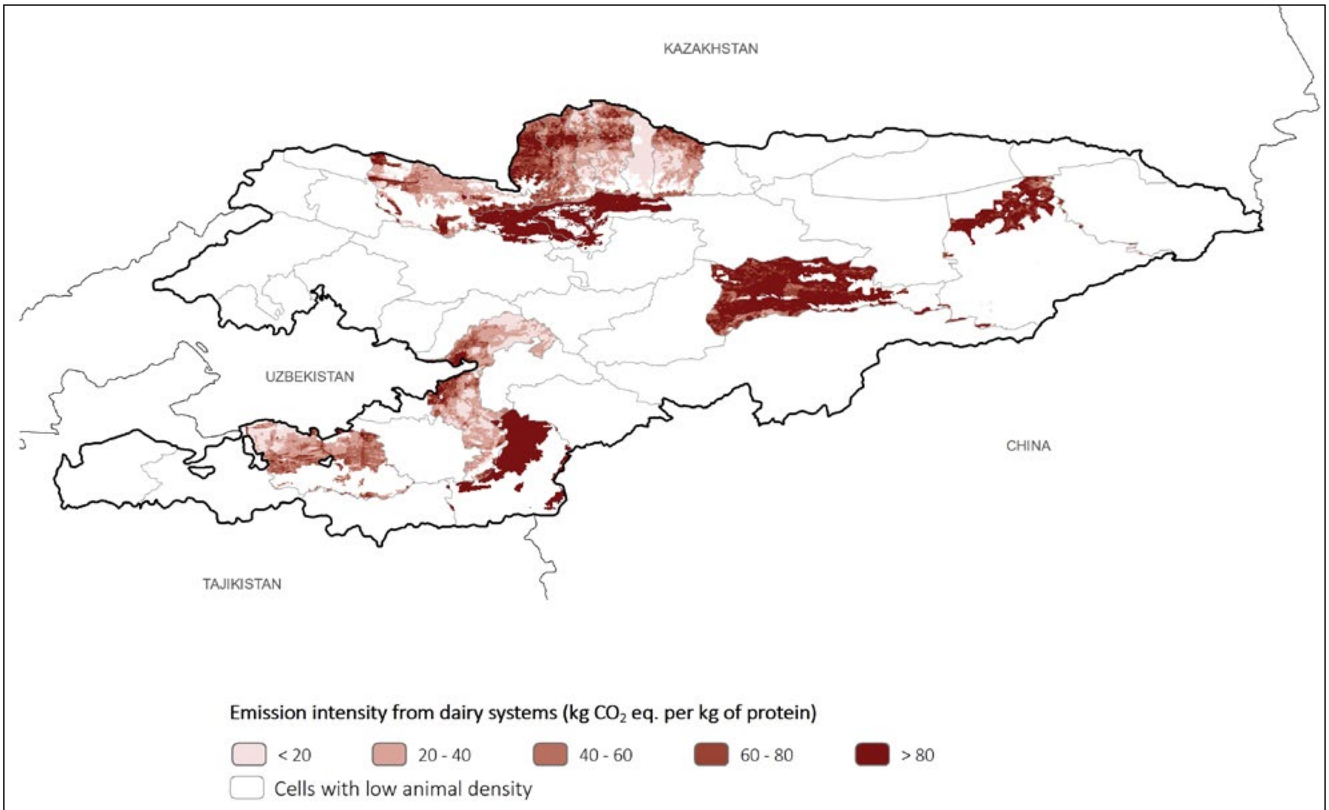
Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

Map 3.3 Regional distribution of emission intensity from dual-purpose cattle systems in Kyrgyzstan



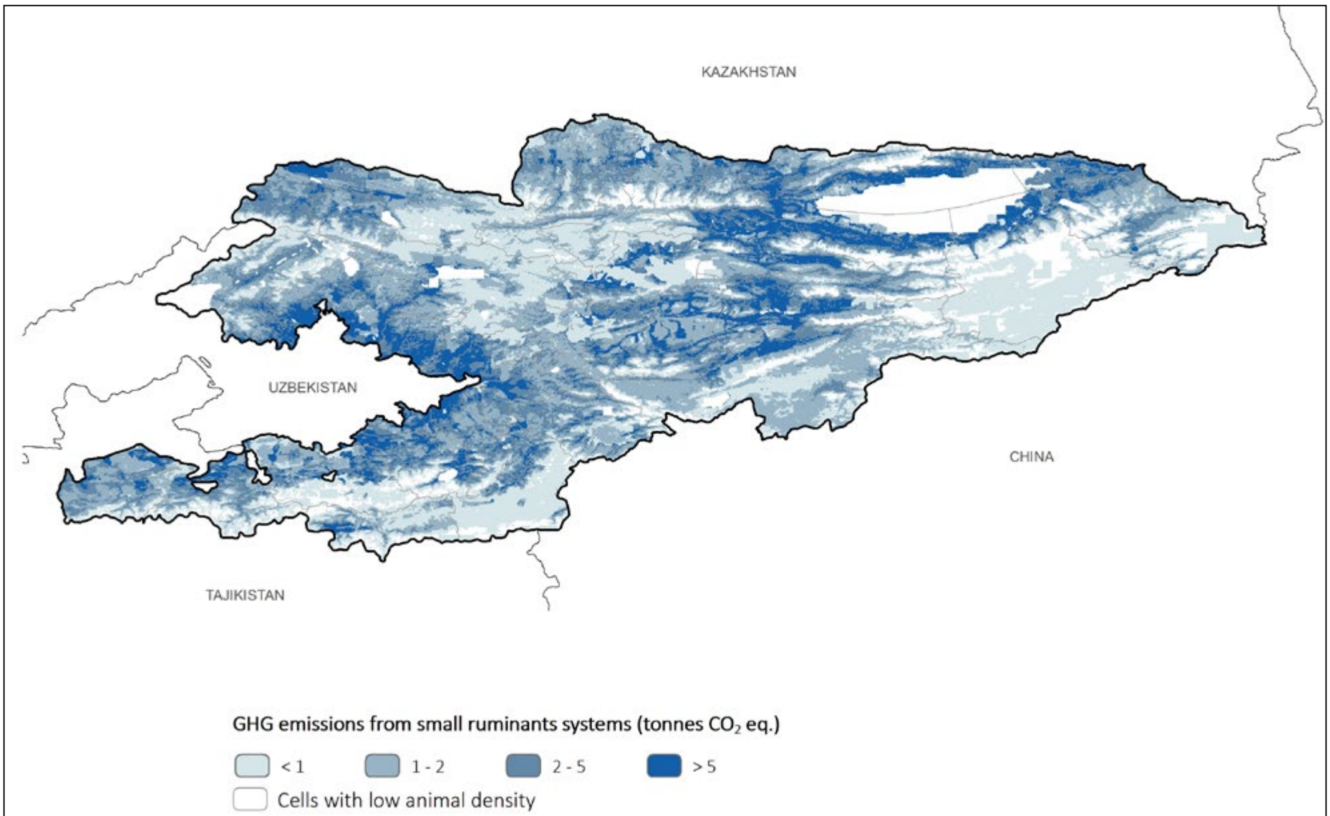
Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

Map 3.4 *Regional distribution of emission intensity from dairy cattle systems in Kyrgyzstan*



Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

Map 3.5 *Regional distribution of total GHG emissions from small ruminant systems in Kyrgyzstan*



Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

Emissions from small ruminant systems are concentrated in the Issyk-Kul, Naryn, and all three oblasts in the southern Kyrgyzstan (Map 3.5).

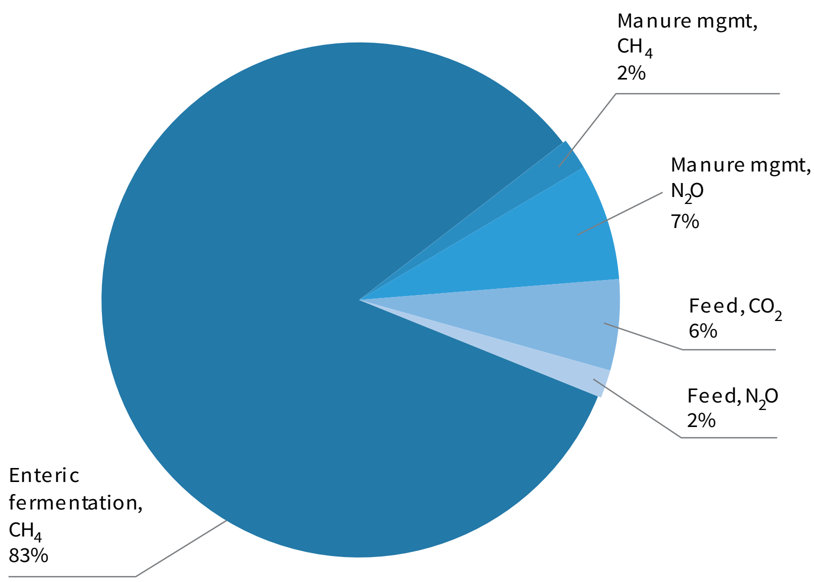
Approximately 83 percent of the emissions arise from enteric methane, 9 percent from the management of stored manure (CH_4 and N_2O) and 8 percent are related to feed production (CO_2 and N_2O; Figure 3.4; all systems combined).

Similar to cattle systems, the feeding practices adopted in small ruminant systems are also affected by seasonality. A larger proportion of the GHG emissions (about 55 percent) from small ruminants are emitted during winter. Moreover, although absolute enteric methane emissions increased by 11 percent during winter, their contribution to total emissions was slightly reduced from 87 to 80 percent from summer to winter, as a result of the increase in emissions related to feed production (CO_2 and N_2O), which were about 2 percent during summer, but represented 11 percent of the total emissions from small ruminants during winter (Figure 3.5; all systems combined).

Among small ruminant systems, emission intensities per unit of protein were on average 327 kg CO_2 eq./kg of protein for sheep intended for wool production, and lower for sheep meat and goats, which were on average 170 and 47 kg CO_2 eq./kg of protein, respectively; Figure 3.6).

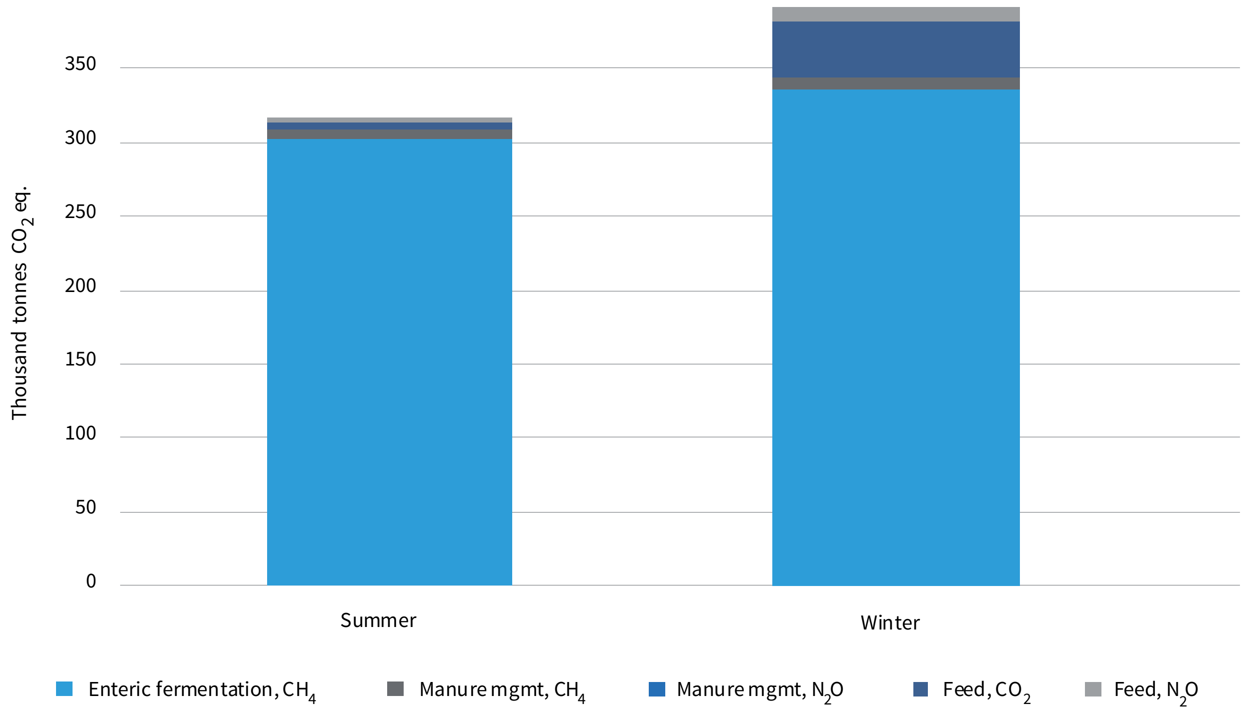
Conversely to cattle systems, the variability in emission intensities for sheep systems (both meat and wool) were narrower, ranging from 323 to 337 kg CO_2 eq./kg of protein for sheep wool and 168 to 175 kg CO_2 eq./kg of protein for sheep meat. This narrow variability reflects the productivity data for these species that were not as disaggregated as the productivity data for cattle. Another reason that might have influenced the estimates of emission intensity and should be considered when analysing these results is that the final products from small ruminants, such as milk and meat, might not be properly accounted in the national production statistics since they are often commercialized in informal markets and/or consumed at the household.

Figure 3.4 Share of total emissions by emission source from small ruminant systems in Kyrgyzstan



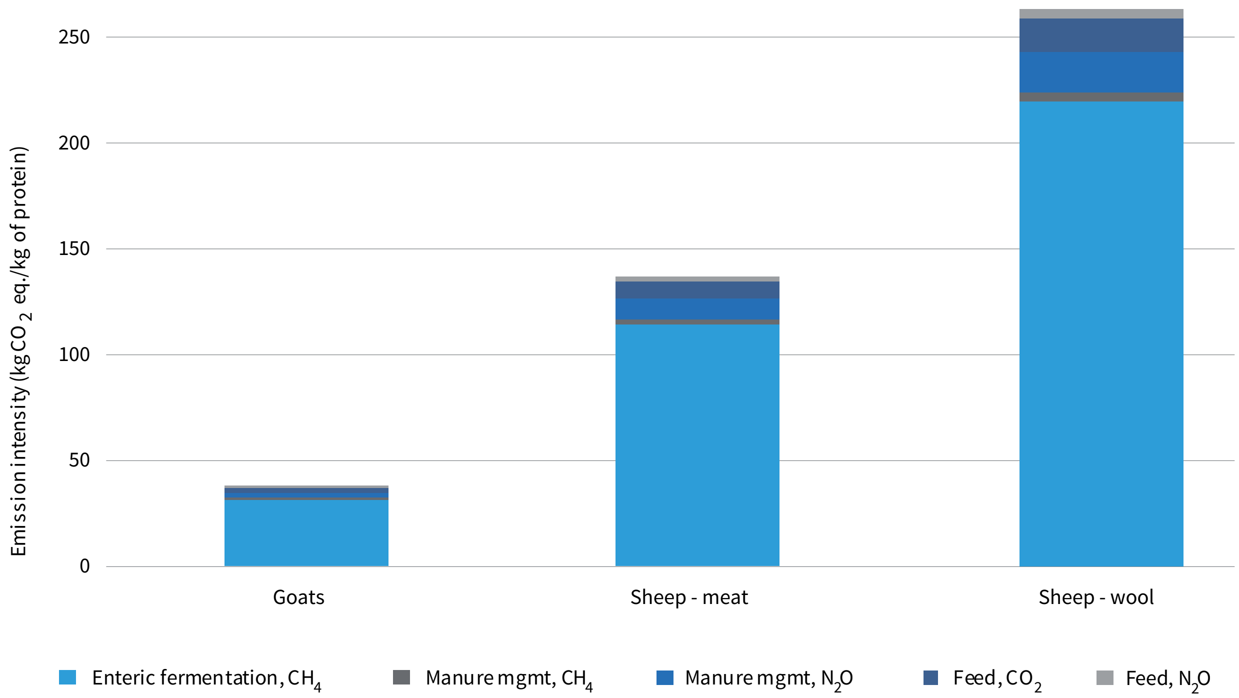
Source: FAO. 2020.

Figure 3.5 *Absolute emissions by small ruminant systems and source by season in Kyrgyzstan*



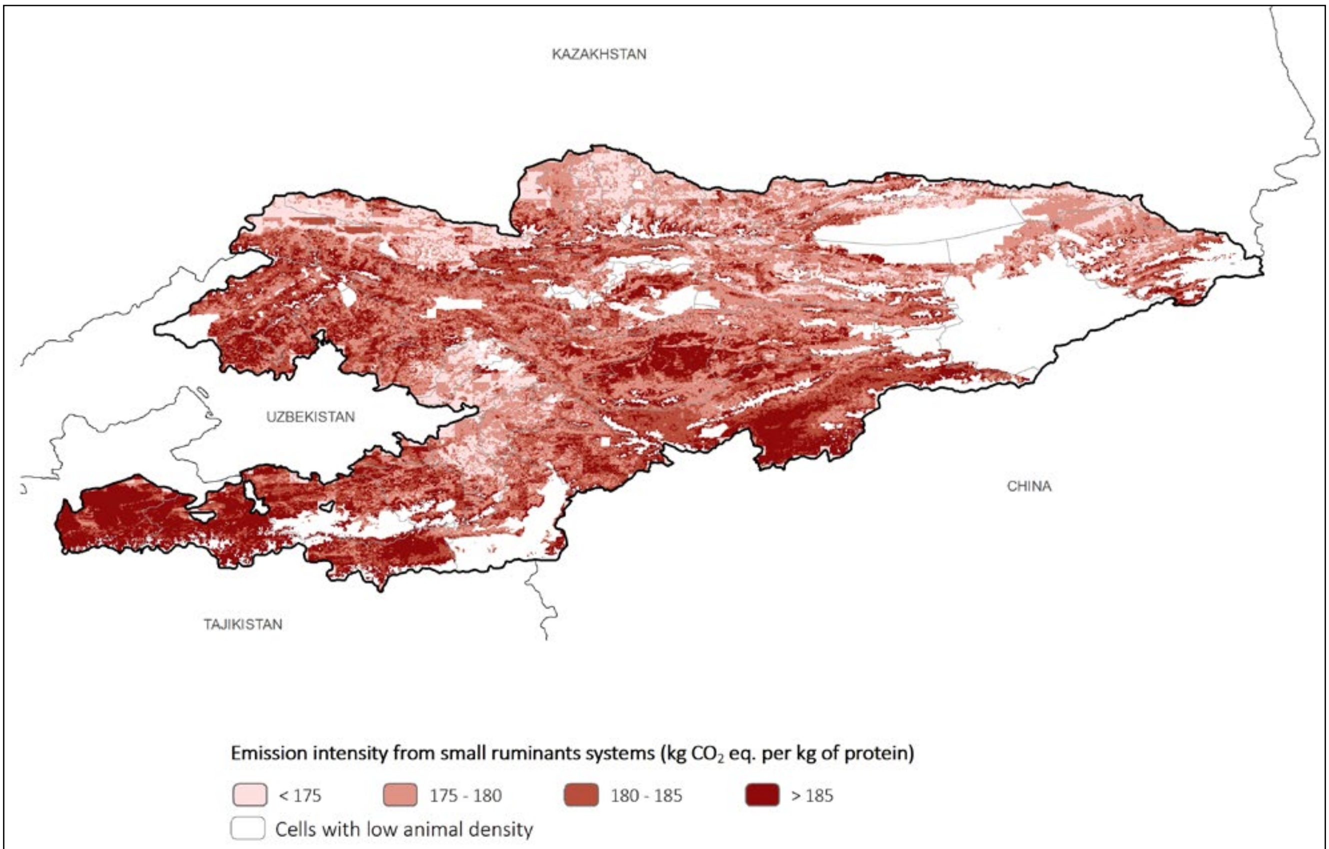
Source: FAO. 2020.

Figure 3.6 *Emission intensity by small ruminant system per year in Kyrgyzstan*



Source: FAO. 2020.

Map 3.6 Regional distribution of emission intensity from small ruminant systems in Kyrgyzstan

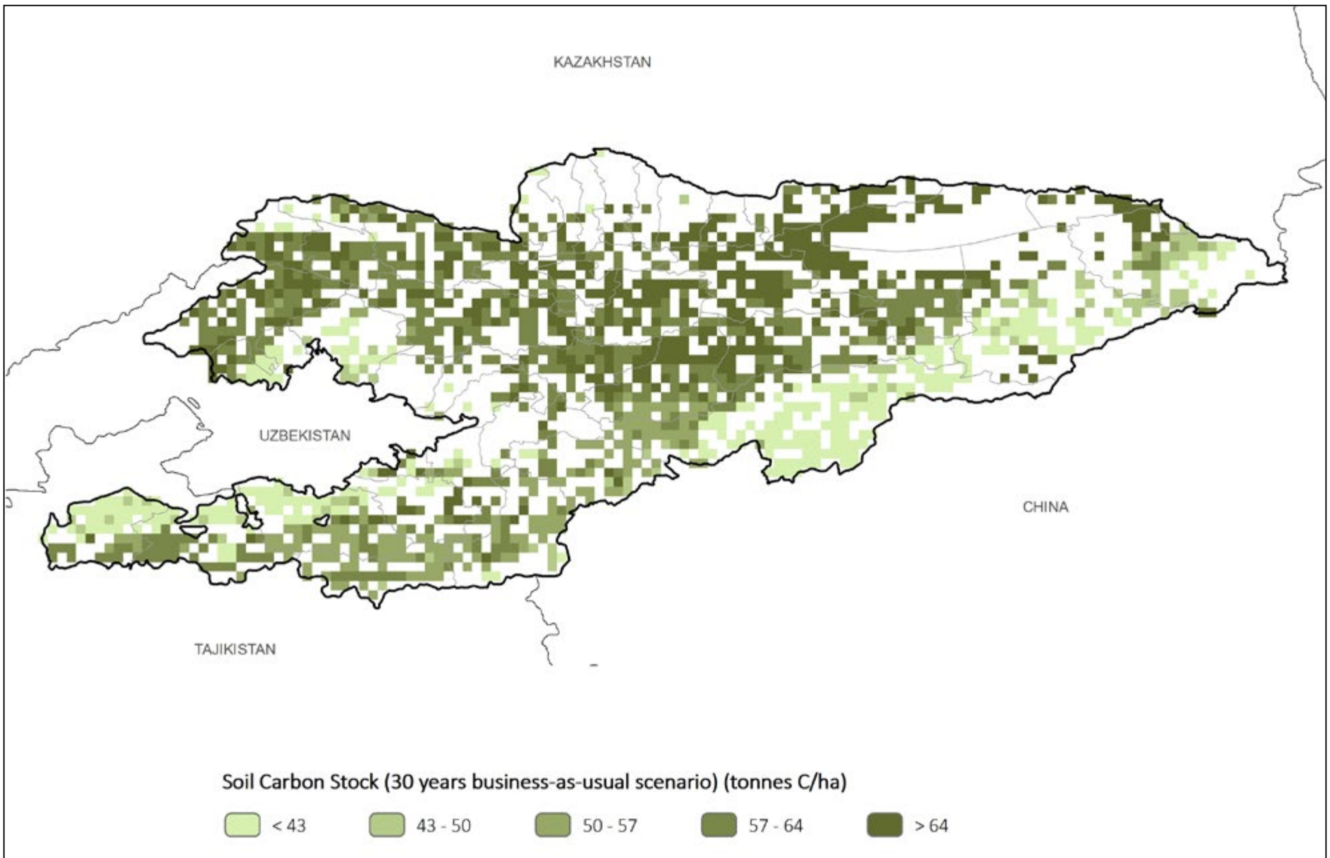


Source: UN, 2020, modified with data from Gilbert et al., 2018, and NSC of the KR, 2019.

SOIL ORGANIC CARBON BASELINE

Estimates suggest that by 2018 the mean carbon content was 57 tonnes C/ha in the top 30 cm soil layer (Map 3.7). Soil carbon stock is increasingly higher from the south to the north of the country, with an ample range going from 22 to 180 tonnes C/ha. This pattern is mainly driven by the carbon inputs to the soil from both manure and plant residues, which are lower in the southern areas compared to the northern areas of the country (Map 3.8b). Within the country, the highest soil carbon stocks are found in the Issyk-Kul region. Interestingly, this is also the oblast with the highest GHG emissions from the cattle systems, which are closely related to the distribution of cattle. The reason for the high carbon content in the region can therefore be attributed to the interaction of three main components: the initial soil carbon content (40 tonnes C/ha), the number of animals and the corresponding amount of excreta deposited in the soil. Indeed, a high number of animals leads to a higher amount of excreta per hectare. The carbon in the excreta is then incorporated in the soil as organic matter. Over time, this carbon is partially stored in the soil and accumulated as organic carbon.

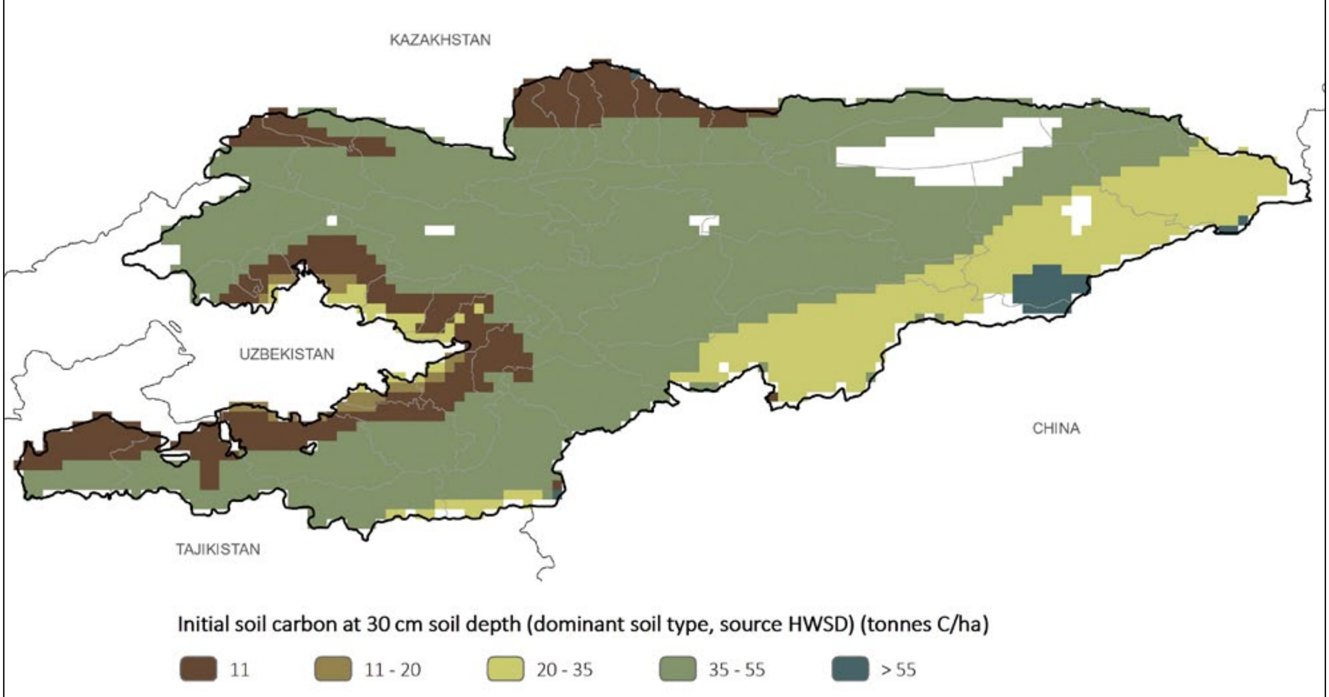
Map 3.7 Soil carbon stocks in Kyrgyzstan



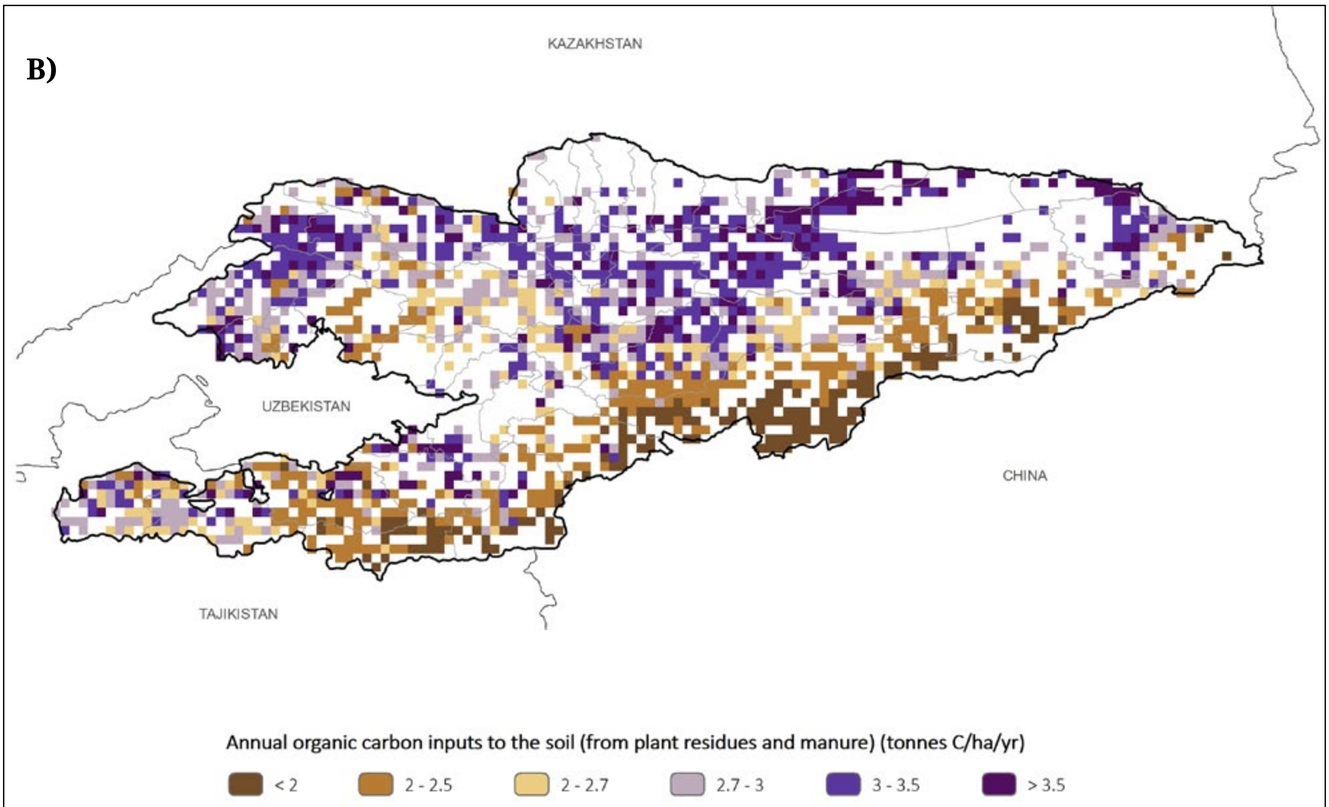
Source: UN, 2020, modified with data from Coleman and Jenkinson, 1996.

Map 3.8 Input data. a) Initial soil carbon at 30cm soil depth; b) annual organic carbon inputs to the soil in Kyrgyzstan.

A)



B)



Source: UN, 2020, modified with data from Coleman and Jenkinson, 1996.

4. Tajikistan

PRODUCTION SYSTEMS

Animal husbandry has a long traditional value and is the vital source of income for more than four million people in Tajikistan. As of 2018, the number of cattle in all categories of farms in Tajikistan amounted to 3 million head (SAPRT, 2020). Of the total cattle herd, 93 percent of the population is under family farms (also called dehkans), while the remaining 7 percent of the cattle population is under collective farms. The goat population is estimated at 1.8 million and the sheep population is about 1.9 million head (SAPRT, 2020). Cattle stocks are concentrated in Khatlon oblast and some of the districts of the Sughd oblast whereas cattle raising practices are almost inexistent in Murghob district in GBAO due to the high altitude (above 4 000 meters). On the other hand, most of the small ruminant stocks are kept in remote mountain pastures of GBAO (northern and eastern Tajikistan), at altitudes from 2 200 to 2 700 meters.

Unlike the large-scale intensive farms typical from the Soviet times, livestock herds are small, and households usually have two cows, five sheep and four goats nowadays (Lerman and Sedik, 2018; Sedik, 2012; Strong and Squires, 2012; Kurbanova, 2012). The majority of animals are owned by unregistered household farms and have no formal access to pastures (Broka *et al*., 2016b). Milking cows usually graze the village pastures, which tend to be overgrazed and receive concentrate supplementation throughout the year. In contrast, the small ruminant stocks graze in pastures for a long period during the year, often the mountain pastures far from the villages (Broka *et al*., 2016b).

As in other countries where animal production is based on grasslands with significant seasonal forage availability, meeting winter-feed requirements is a major issue in Tajikistan (IFAD, 2011, 2015b; World Bank, 2012). In the past, ruminant systems were highly dependent on conserved winter fodder (silages and hay) and on large quantities of grains imported from the Soviet Union. In recent years, the constant increase in the number of animals contrasts with the limited cropland area and reduced grain availability due to cotton and wheat production. This situation has generated an unbalance between feed resources and animal feed demand and has increased the competition for grains directed for feed and human consumption (Sedik, 2012).

Although the yearly transhumance cycles in spring and autumn – during which more than 2 million sheep and goats cross the country, is a key adaptation strategy to environmental variability, the practice also contributes to transmitting infectious and zoonotic diseases. Diseases such as anthrax, flu, tuberculosis, FMD, brucellosis, tuberculosis, rabies, leptospirosis and pestes des petits ruminants (PPR) (Broka *et al*., 2016b) are prevalent in Tajikistan and have contributed to the high mortality levels and poor animal performance. Moreover, the long distance travelled through different climatic conditions, combined with the limited fodder and water availability and other adverse external factors challenge the health and productivity of the small ruminant stock (Azimov, 2019; Kurbanova, 2012).

National data on manure management practices is not available, but it is assumed that a significant part of the manure is deposited on pastures during grazing. When collected, manure is used as fuel. It remains the primary type of fuel used for cooking and heating by rural populations during winter (Azimov, 2019).

GHG EMISSIONS AND EMISSION INTENSITIES

This assessment indicates that the ruminant systems in Tajikistan emitted 11.5 million tonnes CO_2 eq. in 2018, of which 95 percent were emitted by cattle systems (collective and family farms) and 5 percent were emitted by small ruminant systems (goats and sheep).

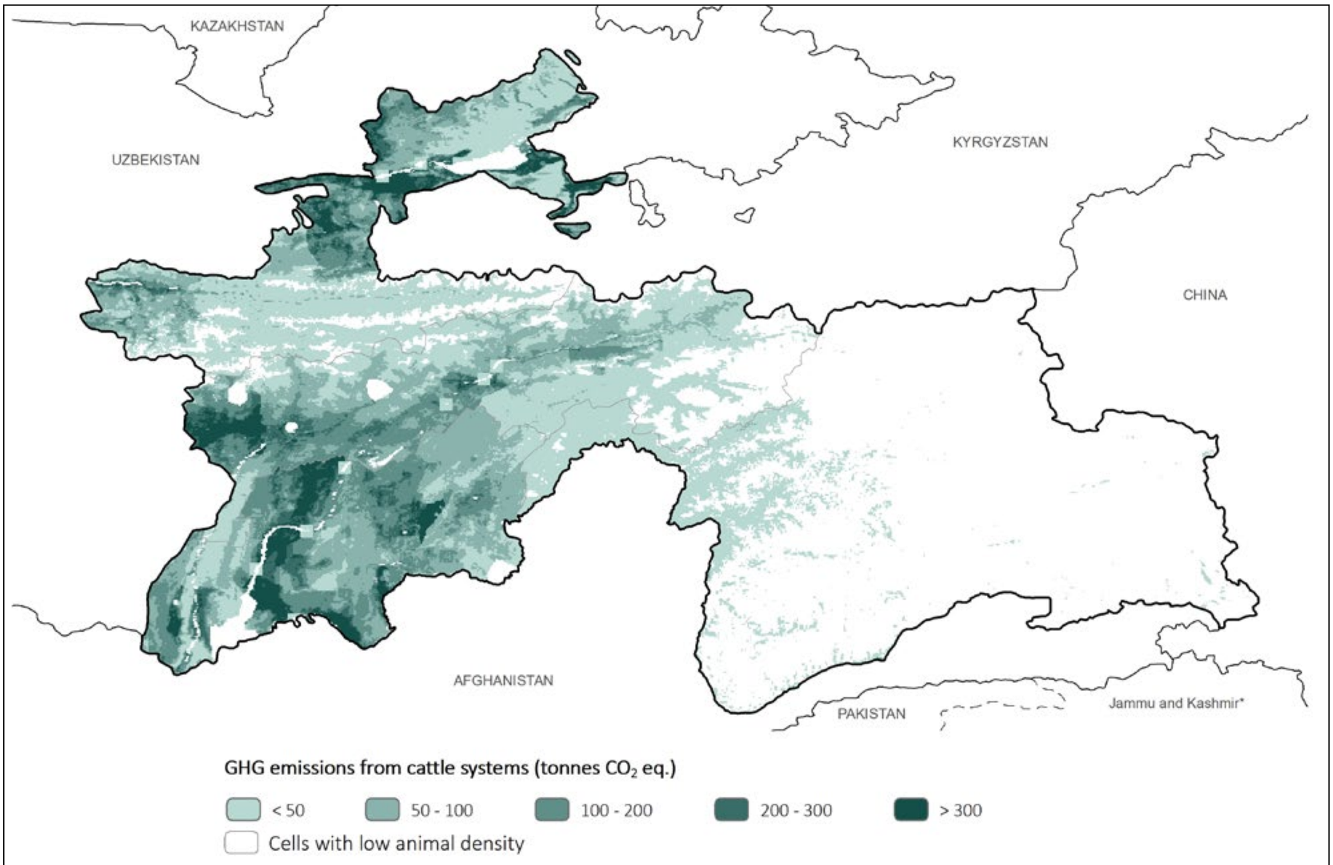
Total GHG emissions distribution from cattle systems (Map 4.1) is closely related to the distribution of cattle, with the majority of the emissions (73 percent) found in the Sughd and Khatlon regions. In contrast, emissions are lower in GBAO region, which is at elevations of greater than 4 000 meters and where cattle raising is almost inexistent.

The activities and processes that contribute towards GHG emissions from cattle systems are shown in Figure 4.1. Approximately 62 percent of the emissions arise from enteric methane, and 20 and 16 percent are derived from CO_2 and N_2O emissions related to feed production, respectively. Emissions arising from manure management (CH_4 and N_2O combined) contribute to 2 percent of overall emissions.

Often emissions from enteric methane are the principal source of emissions in extensive systems, as ruminants are usually fed with pastures and forages, receive low levels of grain supplementation and manure is left on pasture (Strong and Squires, 2012; Sedik, 2012). Although methane emissions from enteric fermentation contribute to the majority of the emissions from cattle systems in Tajikistan, the share of emissions related to feed production are slightly higher than expected for extensive ruminant systems, which is due to the large quantities of concentrate fed to cattle.

At national level, the average emission intensity per unit of protein produced by cattle is 143 kg CO_2 eq./kg of protein (milk and meat); the highest values were estimated for collective systems and the lowest in family systems (Figure 4.2). Average emissions ranged from 75 to 314 kg CO_2 eq./kg of protein for collective systems (Map 4.2) and 103 to 246 kg CO_2 eq./kg of protein for family systems (Map 4.3).

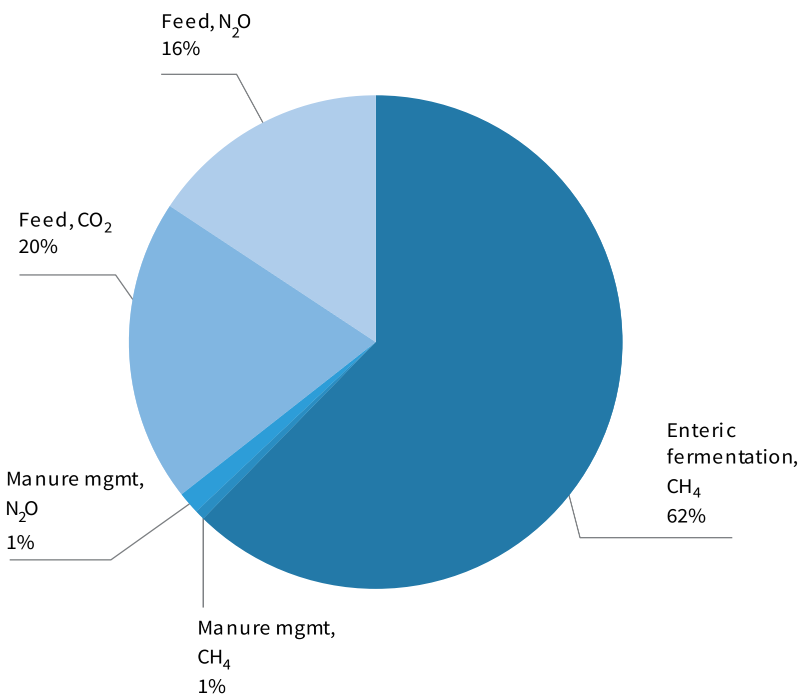
Map 4.1. Regional distribution of total GHG emissions from cattle systems in Tajikistan



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

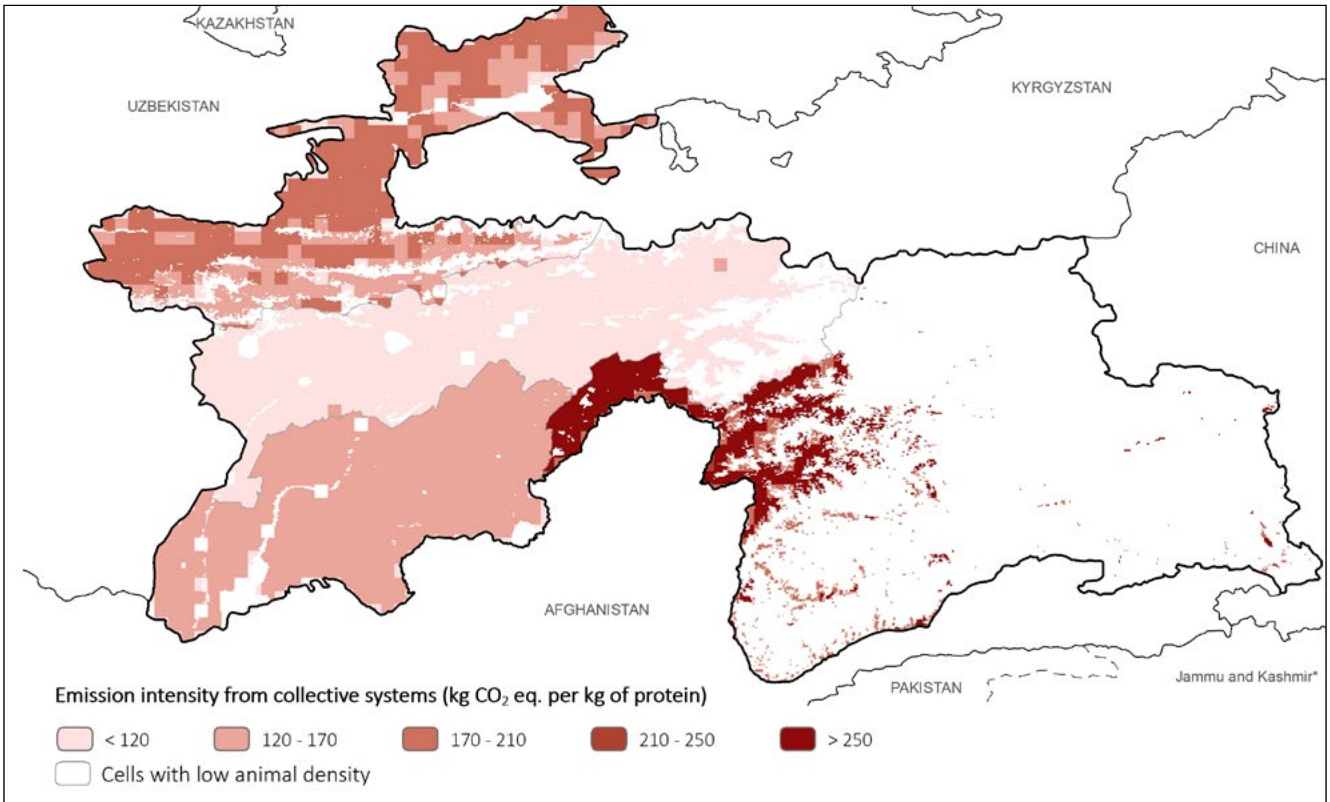
Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

Figure 4.1. Share of total emissions by emission source from cattle systems in Tajikistan



Source: FAO. 2020.

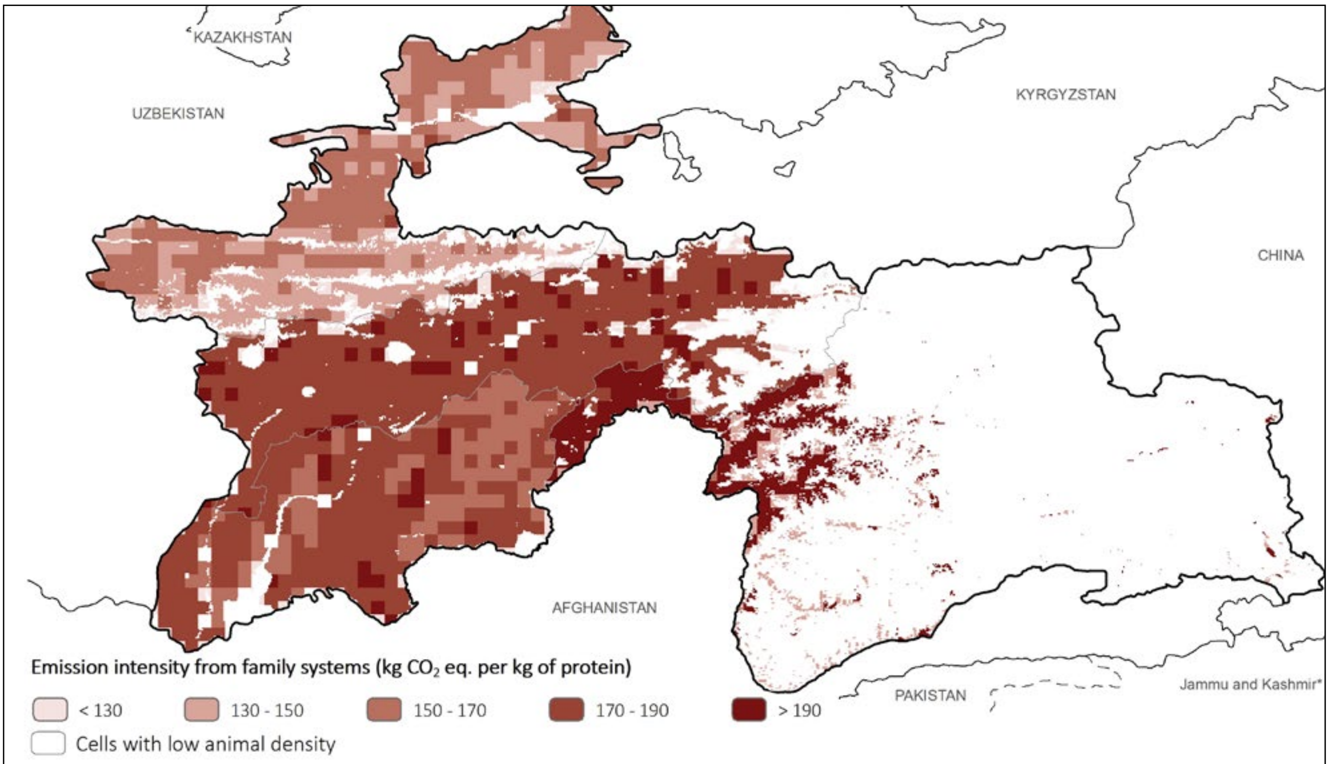
Map 4.2. Regional distribution of emission intensity from collective systems in Tajikistan



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

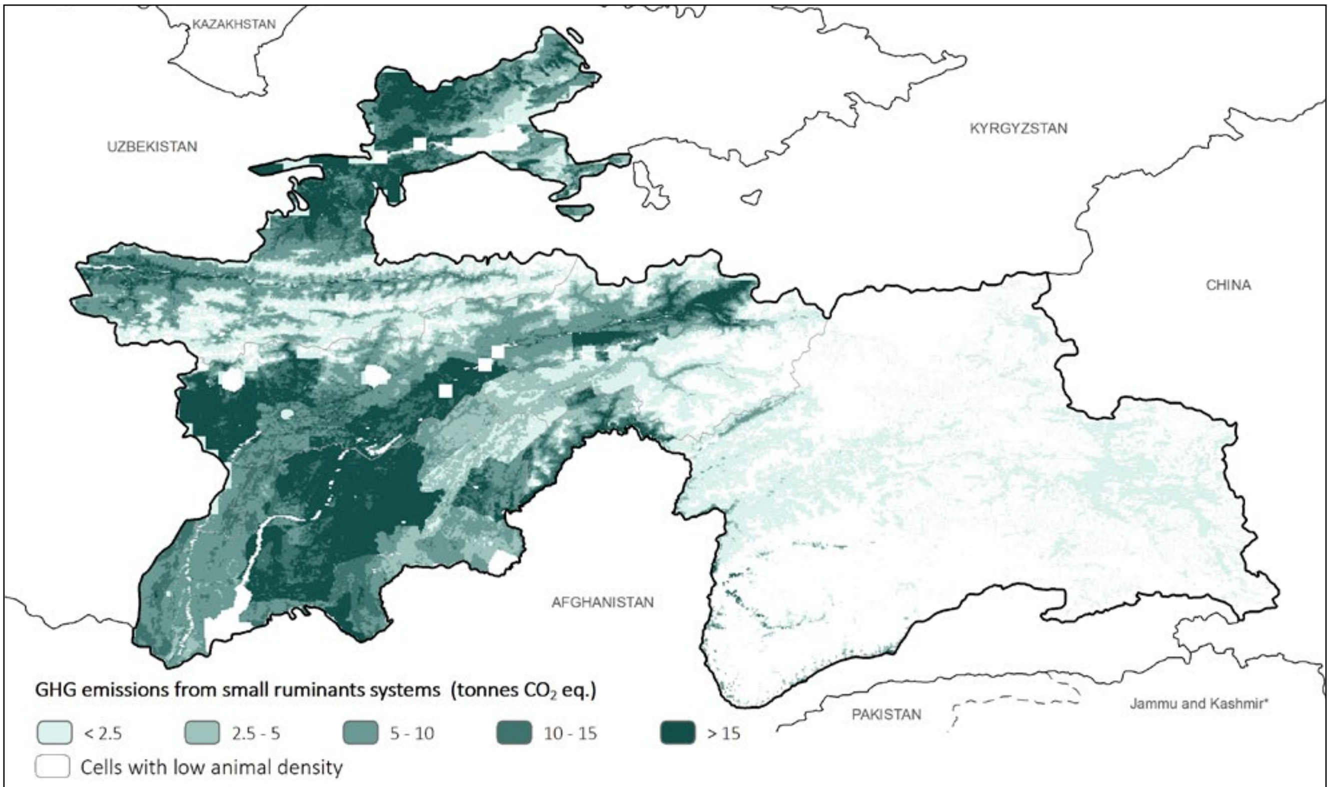
Map 4.3. Regional distribution of emission intensity from family systems in Tajikistan



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

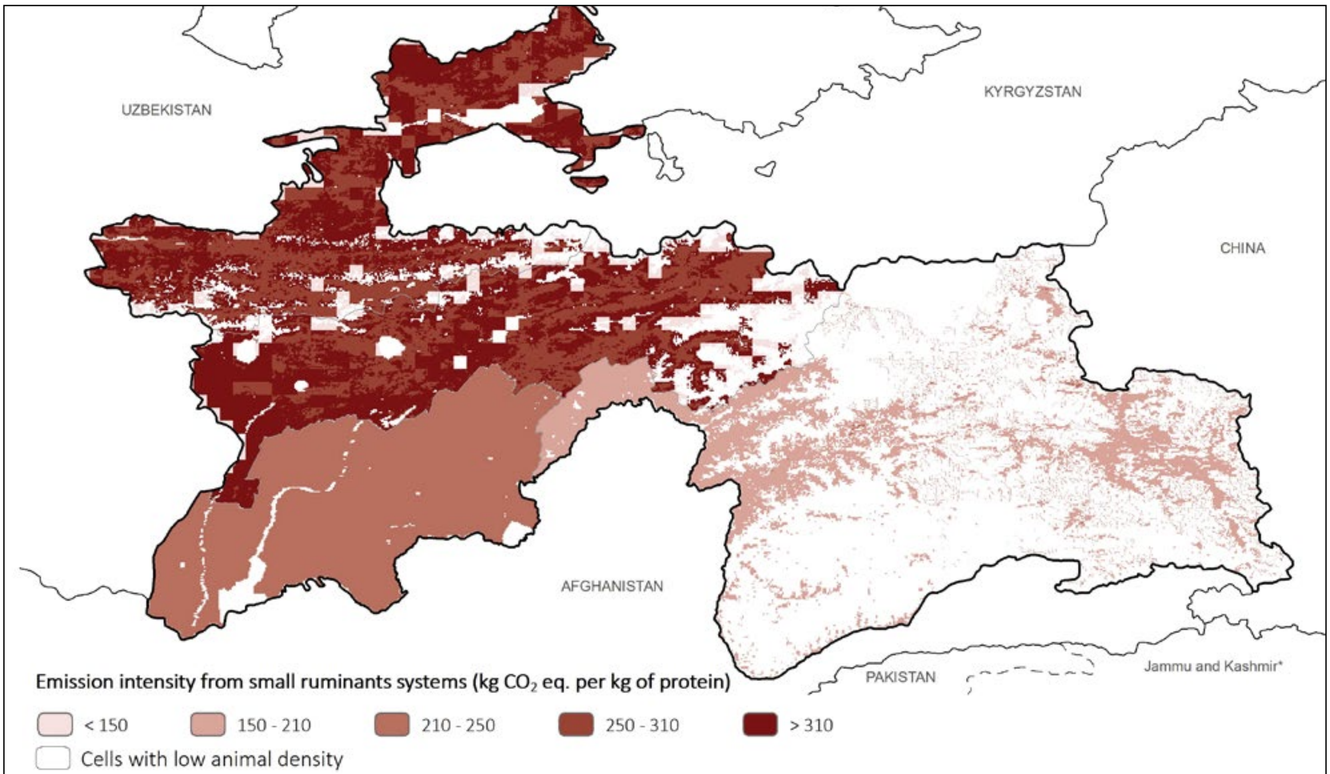
Map 4.4. *Regional distribution of total GHG emissions from small ruminant systems in Tajikistan*



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

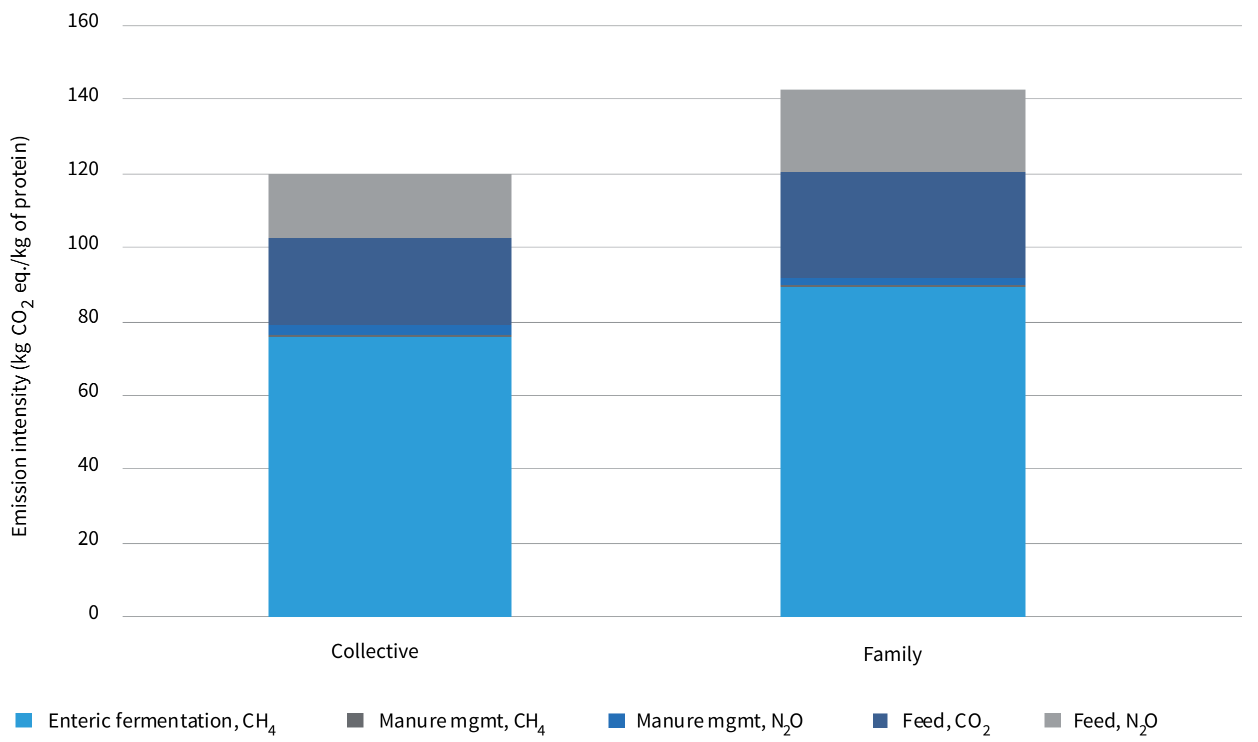
Map 4.5 *Regional distribution of emission intensity from small ruminant systems in Tajikistan*



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

Figure 4.2. *Emission intensity by emission source by cattle production system in Tajikistan*



Source: FAO. 2020.

This wide variation in emission intensity within and between systems is closely related to the level of productivity and the feeding and herd management practices adopted by each system.

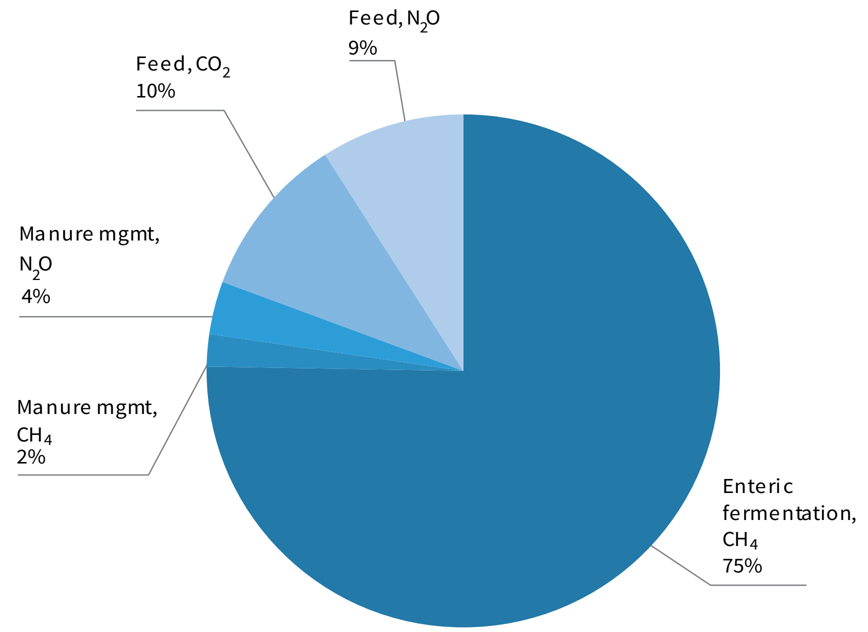
In small ruminant systems, sheep production is responsible for 58 percent (358.7 thousand tonnes CO_2 eq.) of the emissions. In comparison, goats are responsible for emitting 42 percent (259.1 thousand tonnes CO_2 eq.) of the emissions from small ruminants. Emissions from small ruminant systems are concentrated in the Sughd region and in DRS (Districts of Republican Subordination) (Map 4.4).

Approximately 75 percent of the emissions are in the form of enteric methane, 19 percent are derived from feed production practices (CO_2 and N_2O) and the remaining 6 percent are from the management of stored manure (CH_4 and N_2O; Figure 4.3 all systems combined). Small ruminant systems have similar emission profiles, from which enteric methane dominates both profiles, but similar to cattle systems, feed related emissions (both CO_2 and N_2O) are particularly high because of the quantity of grains and by-products that are fed to these animals.

Among small ruminant systems, emission intensities per unit of protein were on average 232 kg CO_2 eq./kg of protein for sheep and 243 kg CO_2 eq./kg of protein for goats (Figure 4.4).

As was the case in Kyrgyzstan, the variability in emission intensities for small ruminants was narrower, ranging from 225 to 261 kg CO_2 eq./kg of protein for goats and 220 to 246 kg CO_2 eq./kg of protein for sheep (Map 4.5). This narrow variability in emission intensities is explained by the level of aggregation of the productivity data for these species and by the underreporting of milk and meat products from small ruminants in the official statistics.

Figure 4.3. Share of total emissions by emission source from small ruminant systems in Tajikistan



Source: FAO. 2020.

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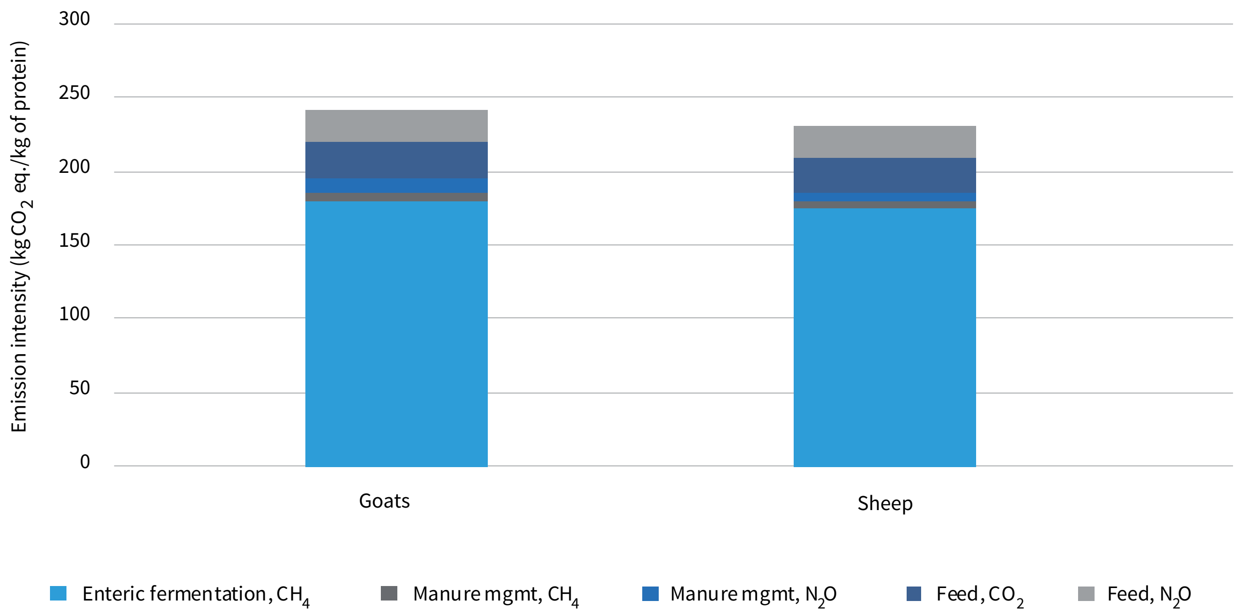
Figure 4.4. *Emission intensity by small ruminant production systems in Tajikistan*



Source: FAO. 2020.

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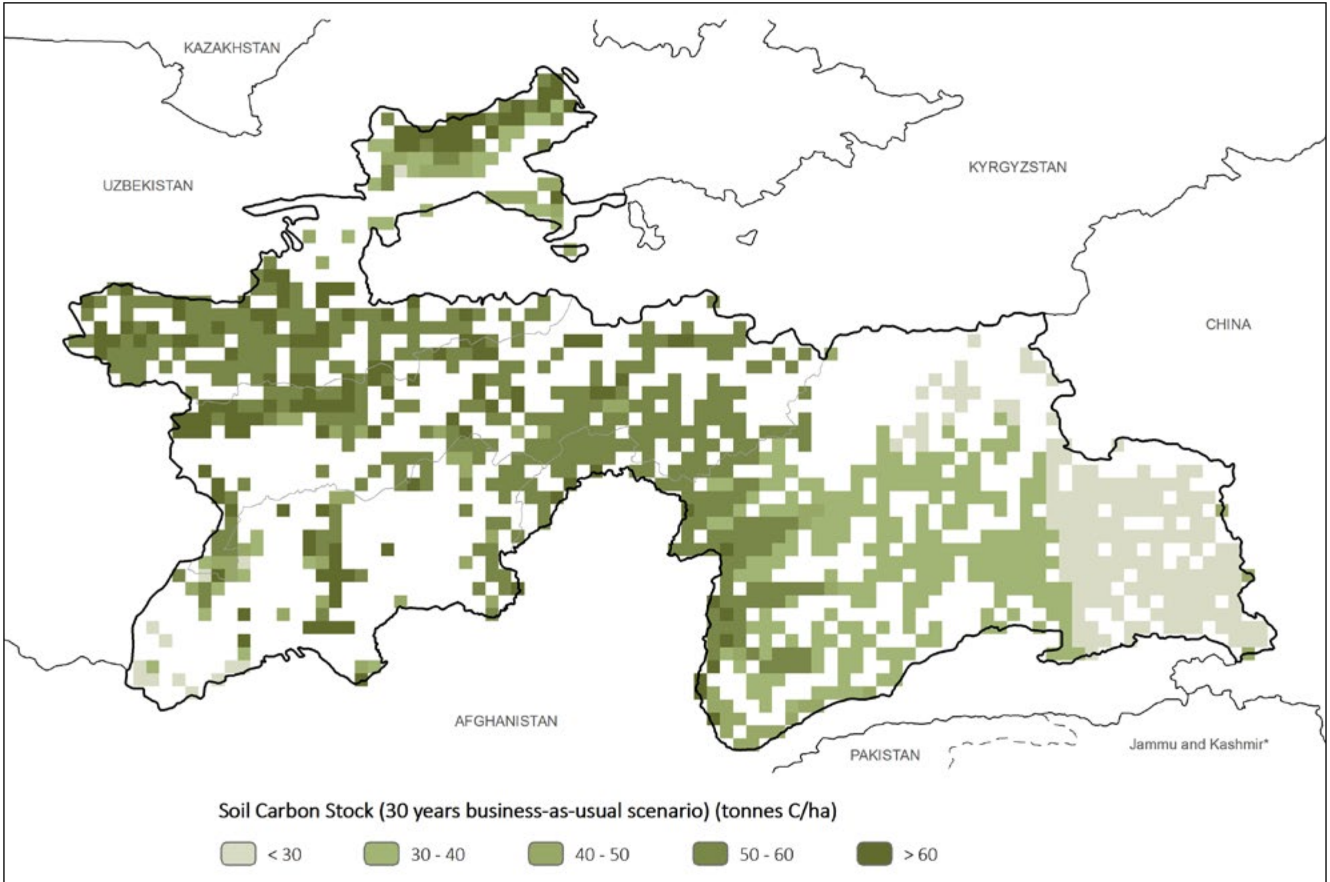
SOIL ORGANIC CARBON BASELINE

Estimates of soil carbon dynamics suggest that by 2018 the carbon content in the top 30 cm soil layer was 46 tonnes C/ha (Map 4.6). Soil carbon stock seems to follow an east to west pattern, with lower soil carbon stocks in the eastern areas, compared to the western regions, and a predicted soil carbon stock range between 12 and 112 tonnes C/ha. The carbon inputs to the soil, from both plant residues and manure, seem to be the main drivers of this carbon pattern (Map 4.7b), regardless of the initial amount of carbon in the soil (Map 4.7). Indeed, carbon stocks and carbon inputs to the soil follow the same geographical distribution, and a strong statistical correlation between the two variables has been found. Indeed, the low carbon inputs to the soil in the Pamir Mountains region is attributable to its extreme topography, with altitudes greater than 4 000 meters and cattle raising almost inexistent.

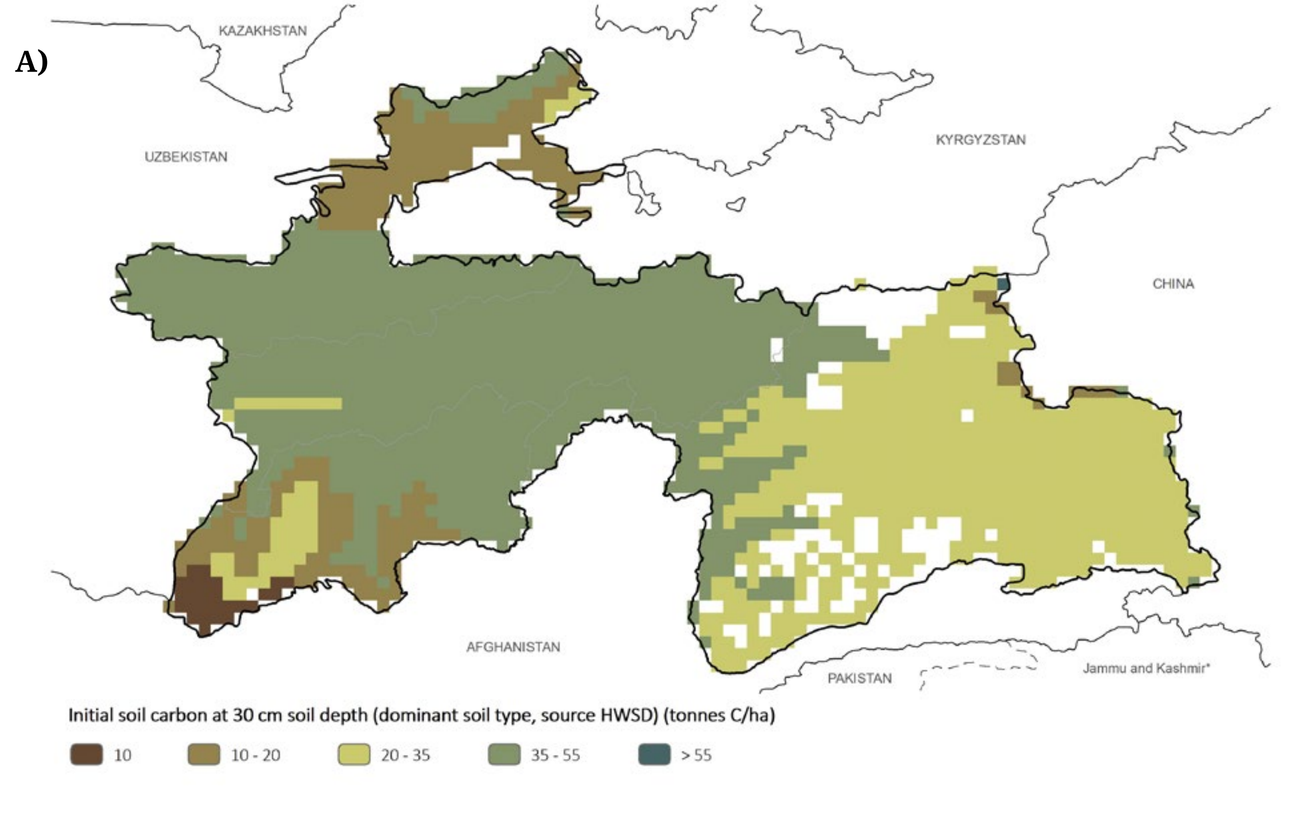
Map 4.6 Soil carbon stocks in Tajikistan

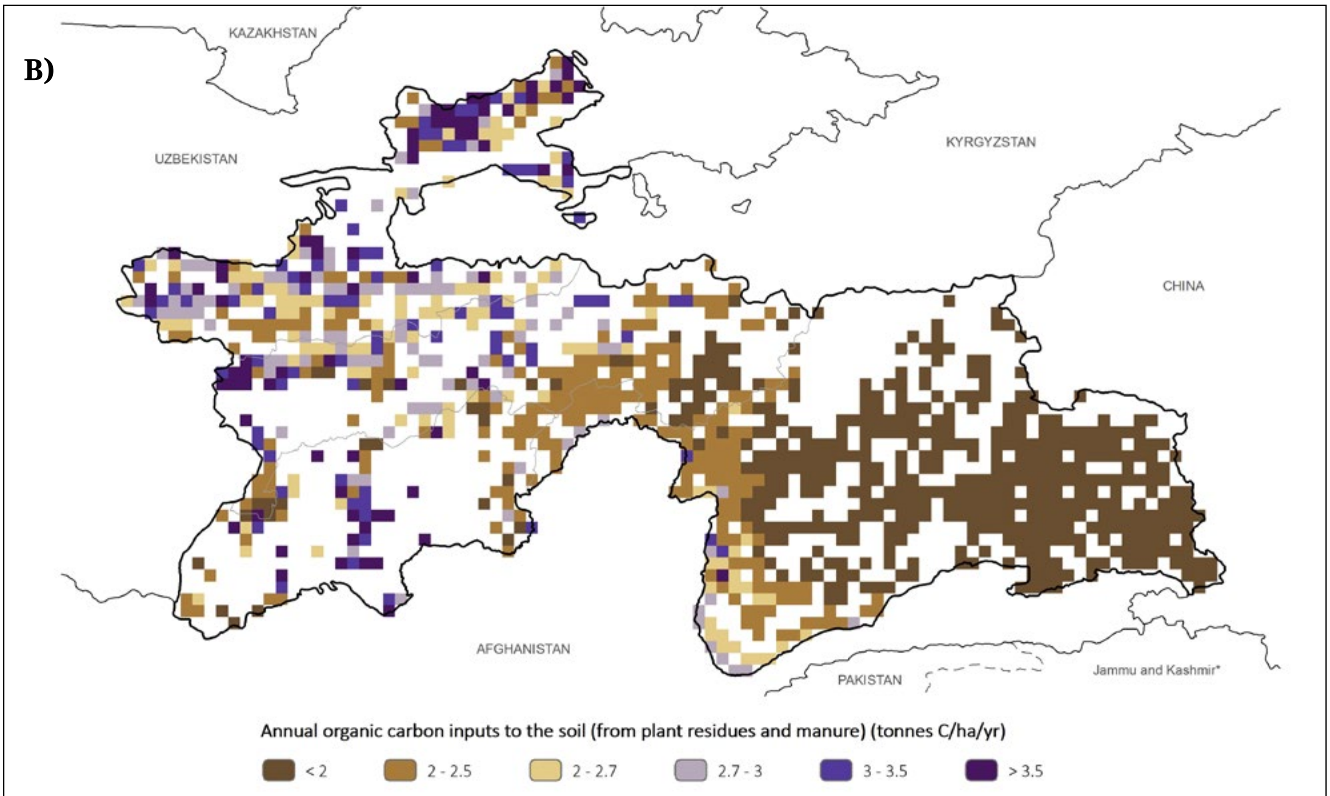


**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

Map 4.7 Input data. a) Initial soil carbon at 30 cm soil depth; b) annual organic carbon inputs to the soil in Tajikistan





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Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

5. Uzbekistan

PRODUCTION SYSTEMS

Animal husbandry is an important economic sector and accounts for 46 percent of Uzbekistan's total agricultural output (UzStat, 2018). In 2018, the stock comprised 14.4 million cattle, 11.6 million sheep, and 4.7 million goats (UzStat, 2020). Ruminant production practices in the country can be divided into three agro-ecological zones: desert and steppe (around 80 % of the country territory with the largest Kyzyl Kum desert in Central Asia), piedmont and highlands that differ in terrain, climate, soil and vegetation type, and water availability (Sutton *et al.*, 2013). The geographic distribution of a diverse range of livestock production systems is largely determined by proximity to population centres and agro-ecological zones.

Dairy production is concentrated in irrigated areas closest to urban centers and is characterized by a higher productivity level (IFAD, 2015a, 2020). Dual-purpose (meat and milk) Bestuzhev breed (crossbreeds of zebu with red-steppe), Bushuyev breed (crossbreeds of zebu and black-motley breed), and beef productions are mostly concentrated in low mountain pastures (World Bank, 2017). The latter local crossbreeds are resistant to parasitic diseases and are well adapted to grazing (Salimova, 2018). Small ruminants used for meat, pelts and wool are mainly raised in desert and steppe locations in the country's western part. The arid zones and desert pastures (78.1 %) are used for Karakul sheep, originated from Bukhara region, given its adaptability to hardiness and ability to thrive under adverse conditions. In foothill and mountain dry zones, "Zhaidar" meat-fat sheep breed, "Akhangaran" meat-wool sheep, and Uzbek black goat breeds are raised (Ruzibaev, 2019).

The seasonal grazing movements vary depending on the agro-ecological zones. In desert and steppe zones, grazing is practiced all year round. In the piedmont and highland zones, animals graze on the near village pastures (from February to mid-June). From May–June to mid-October, the herd is transferred to the highland pastures. From the beginning of October, livestock is moved down for post-harvest grazing to the rainfed agricultural lands and later to the irrigated lands. In these areas, animals are grazed up to two months (Lal, 2004; Shaumarov *et al*., 2012; Squires and Feng, 2017).

Since independence, Uzbekistan's agricultural reform pattern has involved multiple changes in farm sizes and specialization that affected ruminant productivity (Zorya, Djanibekov and Petrick, 2019). Overall, the agricultural area has decreased by 33 percent, while the ruminant stock has increased by 45 percent, leading to a pronounced insufficient feed supply (World Bank, 2017). Most of the area allocated to fodder production was substituted by wheat and cotton production, leading to a reduction in the fodder cultivated area to almost 70 percent compared to the fodder cultivated area sown during the Soviet times. The pasture area has also been reduced by approximately 40 percent because of low productivity and drained bottom areas around the desiccated Aral Sea. One of the realistic implications of preventing these negative processes was forest reclamation of the degraded area. Therefore, the degraded pastures were placed under the State Nature Reserve or State Forest Fund authorities for planting purposes (Botman, 2009). Additionally, the fragmentation of large farms into individual farms led to an overall reduction of the pastures and fodder sources (UNDP, 2010; Zorya, Djanibekov and Petrick, 2019). Declining pasture quality caused by the increase of the ruminant herd, unsystematic pasture use, and overgrazing is another concern that contributes to the critical state of the animal feed supply in Uzbekistan (GEF, 2019; JICA, 2017; World Bank, 2017).

Echinococcosis, fascioliasis, rabies, brucellosis, FMD and tuberculosis are the main animal diseases found in Uzbekistan that cause significant mortality and morbidity rates and contribute to significant financial losses in socio-economic development. Inadequate health and veterinary services combined with limited laboratory and surveillance system capacity are the root causes of the high incidence of these diseases (Mukimov, 2019).

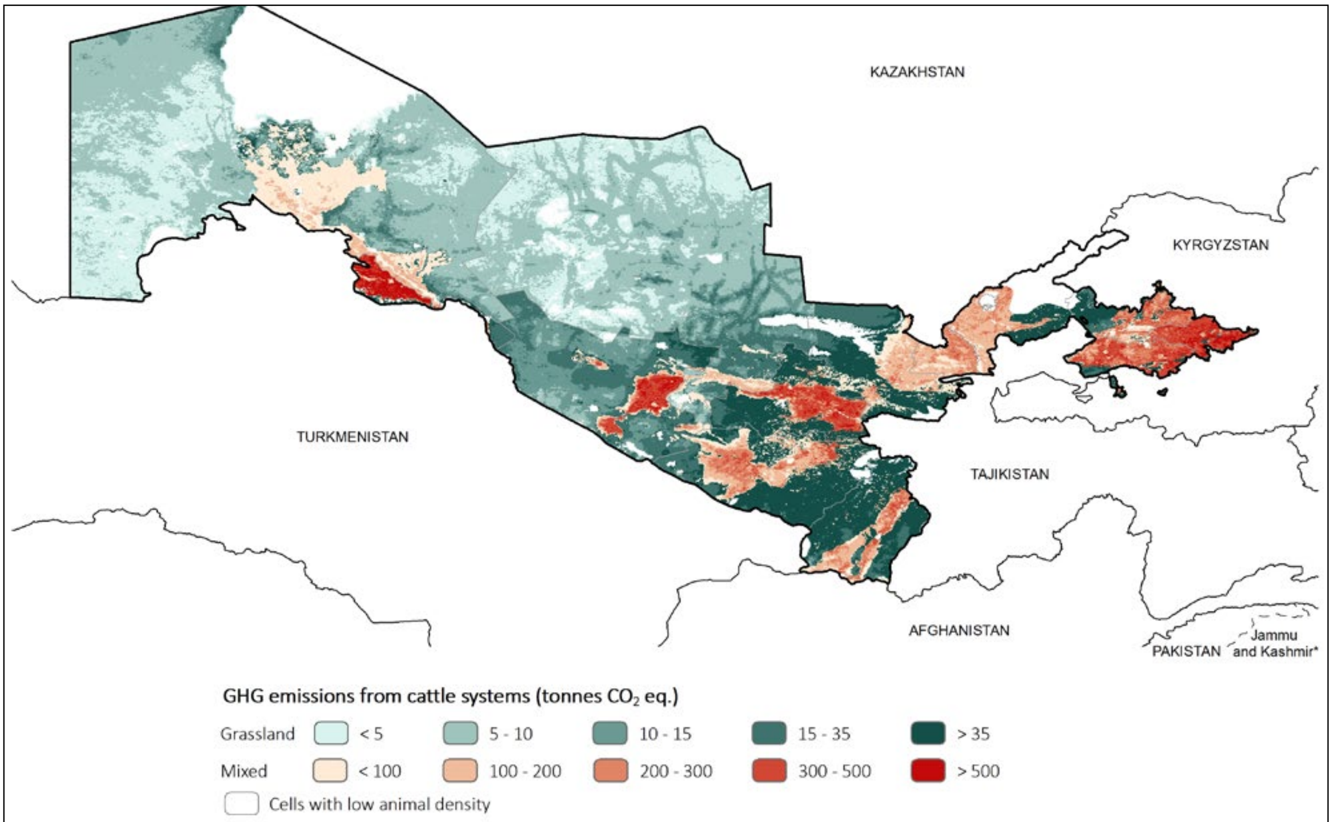
The manure from sheep and cattle kept in stalls and household yards is collected and used for heating and cooking by rural households during winter. Part of the manure collected is also used as organic fertilizer; however, official information on manure management and purpose for each production system and region is not available. Despite the low number, biogas plants have been recently established for biogas production in Khorezm, Kashkadarya, Syrdarya and Namangan oblasts (Mukimov, 2019).

GHG EMISSIONS AND EMISSION INTENSITIES

Ruminant systems in Uzbekistan emitted 42.6 million tonnes CO_2 eq. in 2018, from which 83 percent was emitted by cattle systems (mixed and grassland) and 17 percent was emitted by small ruminant systems (goats and sheep).

This study found that in 2018, the cattle production systems emitted 35.4 million tonnes CO_2 eq. Total GHG emissions distribution from cattle production systems (Map 5.1) is closely related to the distribution of cattle, with about 35 percent of the emissions being found in the fertile lands of Fergana Valley, particularly in Andijan oblast. In contrast, emissions are lower in the desertic north-central and northwest regions given the low cattle density.

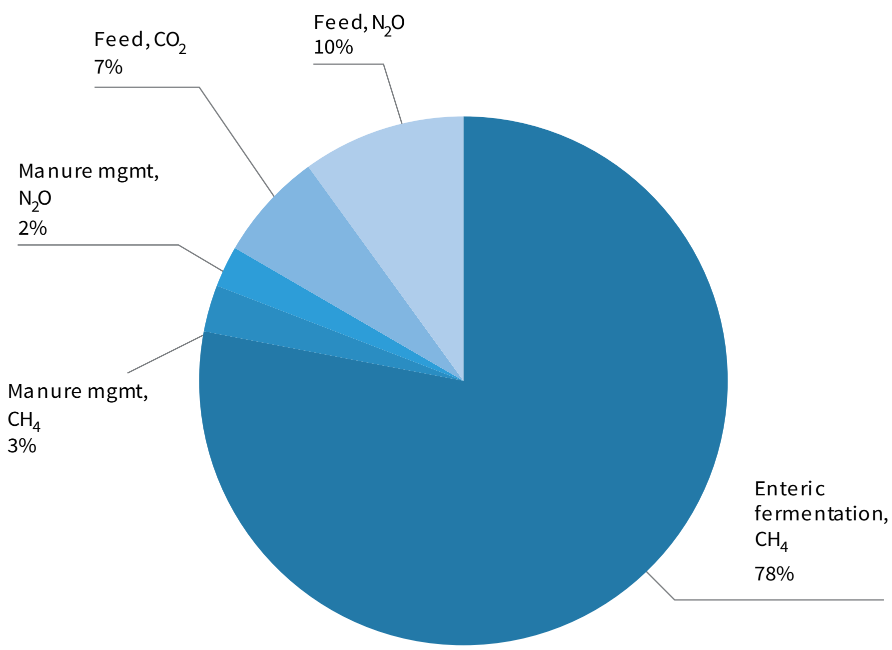
Map 5.1 *Regional distribution of total GHG emissions from cattle systems in Uzbekistan*



Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Source: UN, 2020, modified with data from Gilbert et al., 2018, and SAPRT, 2020.

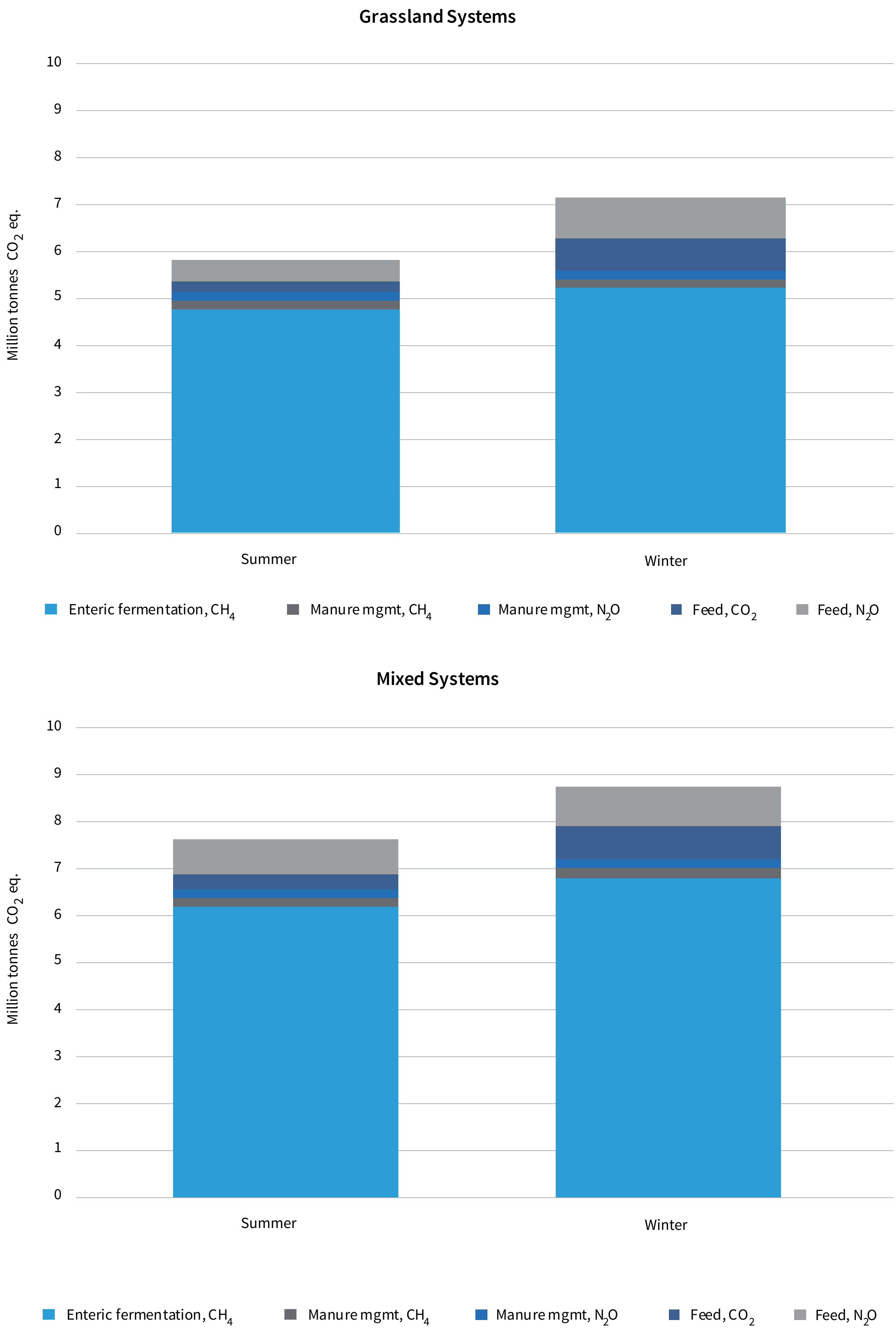
Figure 5.1 *Share of total emissions by emission source from cattle systems in Uzbekistan*



Source: FAO. 2020.

Uzbekistan

Figure 5.2 *Absolute emissions by cattle systems and source by season in Uzbekistan*



Source: FAO. 2020.

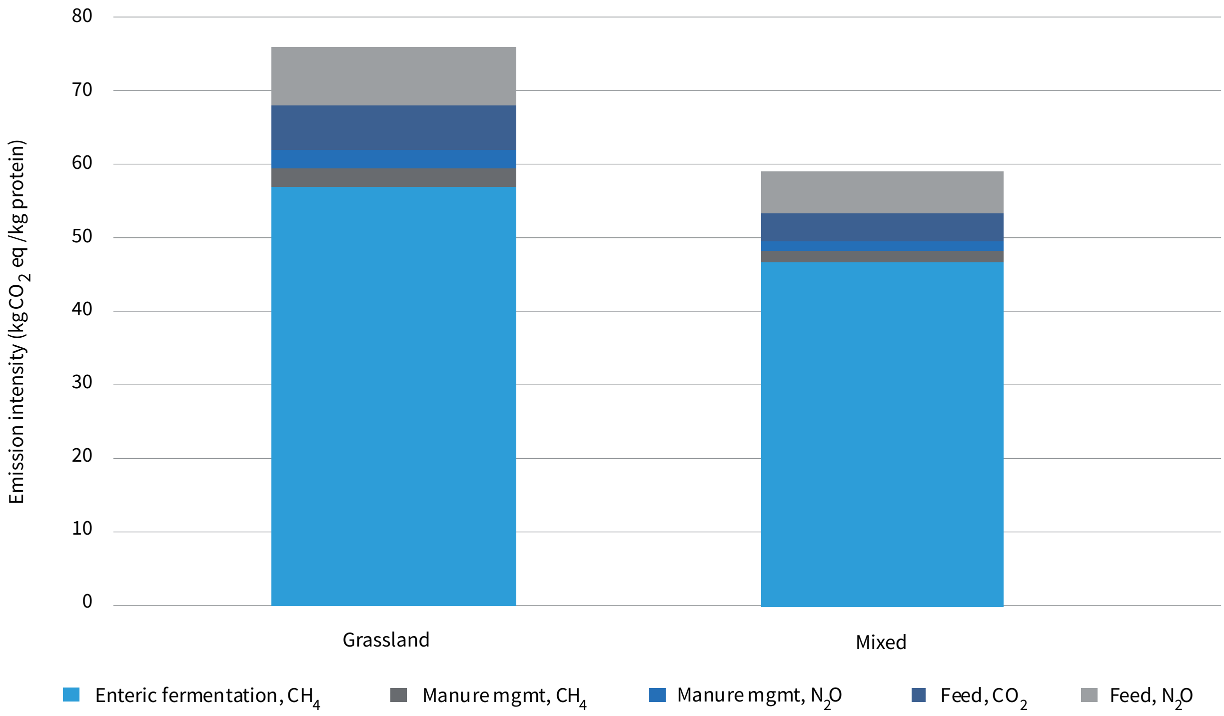
Within the cattle systems, mixed systems, which produce 77 percent of the national ruminant protein supply (milk and meat), are responsible for 72 percent (25.5 million tonnes CO_2 eq.) of the total GHG emissions, while grassland systems contribute 28 percent of the emissions (9.9 million tonnes CO_2 eq.). Enteric methane is the predominant source of emissions from cattle systems in Uzbekistan (78 percent), followed by emissions related to feed production (17 percent; N_2O and CO_2 combined) and manure management (5 percent; N_2O and CH_4 combined; Figure 5.1).

Cattle feed rations drastically change from summer to winter. During summer, feed rations are mainly composed of fresh grasses with minimal grain supplementation. During winter, fresh grasses are substituted by preserved forages (hays and silages), supplemented with greater amounts of fodder beets, agro-industrial by-products, and crop residues. The study found that 54 percent of the emissions were emitted during winter and 46 percent were emitted during summer. In terms of absolute emissions, enteric emissions increased by 10 percent during winter, but their contribution to total emissions was reduced from 81 to 75 percent from summer to winter. Overall, absolute emissions from all sources, except N_2O emissions from manure management, increased during winter given the different feeding practices (Figure 5.2).

At the national level, the emission intensity per unit of protein produced by cattle is on average 68 kg CO_2 eq./kg of protein (milk and meat). In contrast, the emission intensity by production system is about 76 and 59 kg CO_2 eq./kg of protein for grassland and mixed systems, respectively (Figure 5.3). Average emissions ranged from 49 to 156 kg CO_2 eq./kg of protein for grassland systems and 42 to 126 kg CO_2 eq./kg of protein for mixed systems (Map 5.2). There is a wide variation in emission intensity across the country as this indicator is closely related to the level of productivity at the regional level. Emission intensity is particularly high in the desert regions of Karakalpakstan, Khorezm and in a narrow belt along the Amudarya River in Karakalpakstan, because of the climatic conditions in these regions that hamper cattle productivity.

Small ruminants emitted 7.2 million tonnes CO_2 eq. in Uzbekistan in 2018, with sheep accounting for 5.2 million tonnes CO_2 eq. and goats for 2 million tonnes CO_2 eq. Emissions from small ruminant systems are concentrated in the fertile regions of

Figure 5.3 Emission intensity by cattle production systems in Uzbekistan



Source: FAO. 2020.

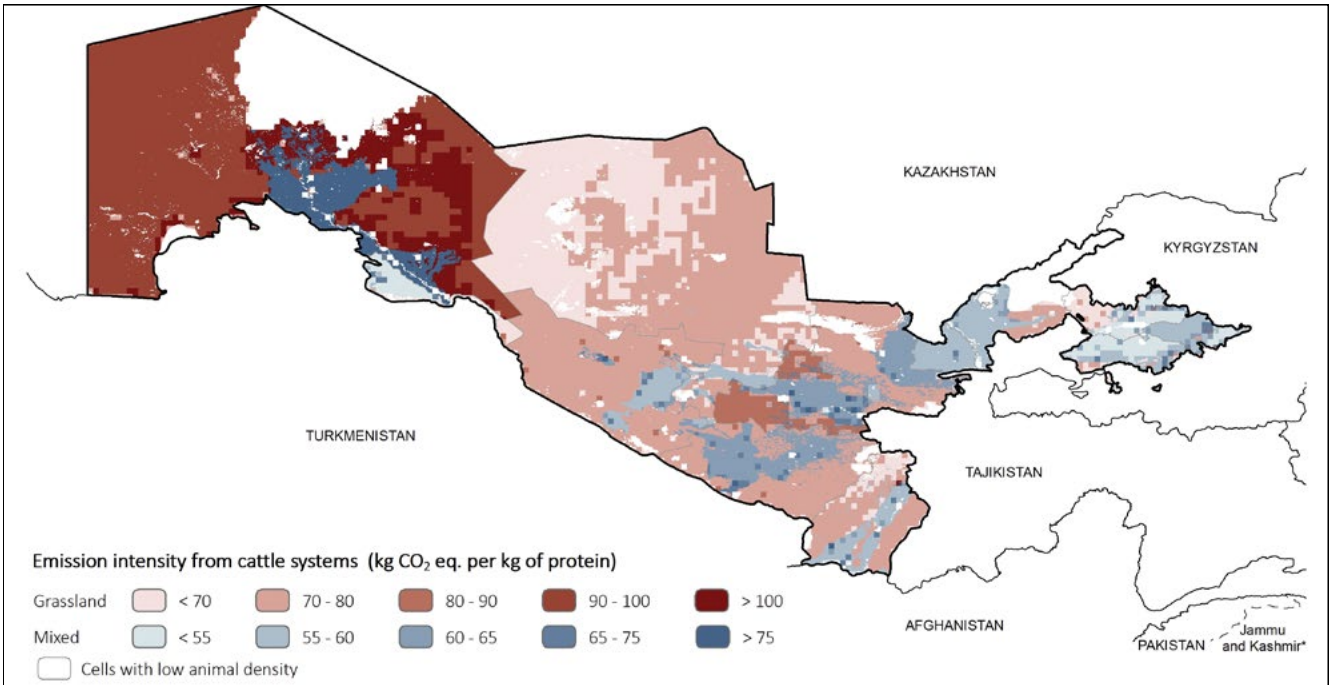
Fergana Valley, in the southern regions of the country (Kashkadarya, Surkhandarya oblasts) and in the central regions (Samarkand, Jizzakh oblasts), reflecting the high density of animals in these areas compared to other parts in the country (Map 5.3).

Approximately half of the emissions arise from enteric methane; 35 percent is related to feed production (CO_2 and N_2O) and 13 percent related to manure management (CH_4 and N_2O; Figure 5.4; sheep and goats combined). The relatively lower contribution of enteric methane to total GHG emissions can be explained by the lower availability of fresh pasture and the more prevalent use of conserved forages and crop residues, which are also linked to a significant share of feed related emissions.

Conversely to cattle systems, information related to the feeding practices by season was not available for small ruminants, so the effect of seasonality could not be modelled.

Among small ruminant systems, average emission intensities per unit of protein were on 299 kg CO_2 eq./kg of protein for sheep and, 269 kg CO_2 eq./kg of protein for goats (Figure 5.5). The variability in emission intensities for sheep was narrower, ranging from 269 to 353 kg CO_2 eq./kg of protein, compared to a range of 252 to 316 kg CO_2 eq./kg of protein for goats (Map 5.4). This narrower variability in small ruminant emissions reflects lower level of disaggregation in the productivity data for these species compared to those from cattle. A further reason may be higher levels of home consumption and informal marketing resulting in lower reporting rates for small ruminants in the national statistics.

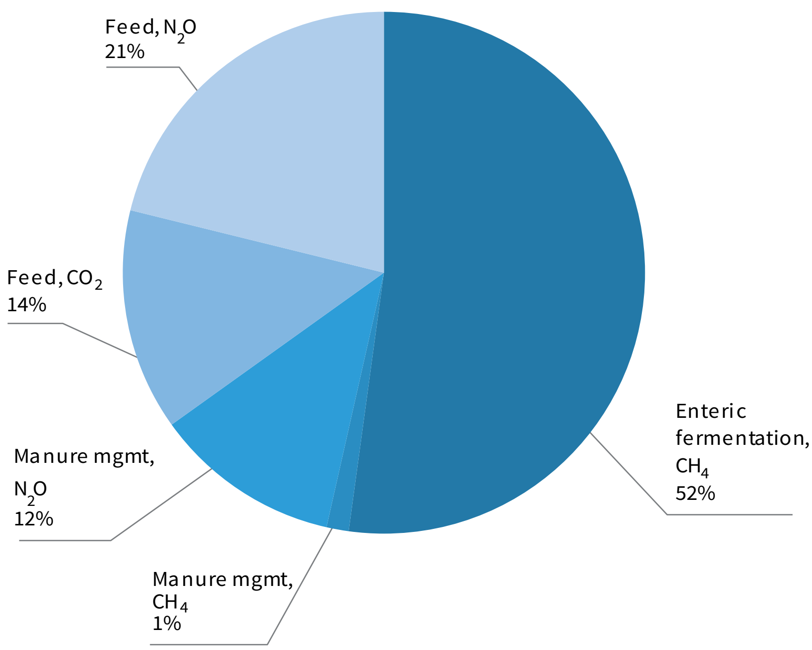
Map 5.2 Regional distribution of emission intensity from cattle systems in Uzbekistan



**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

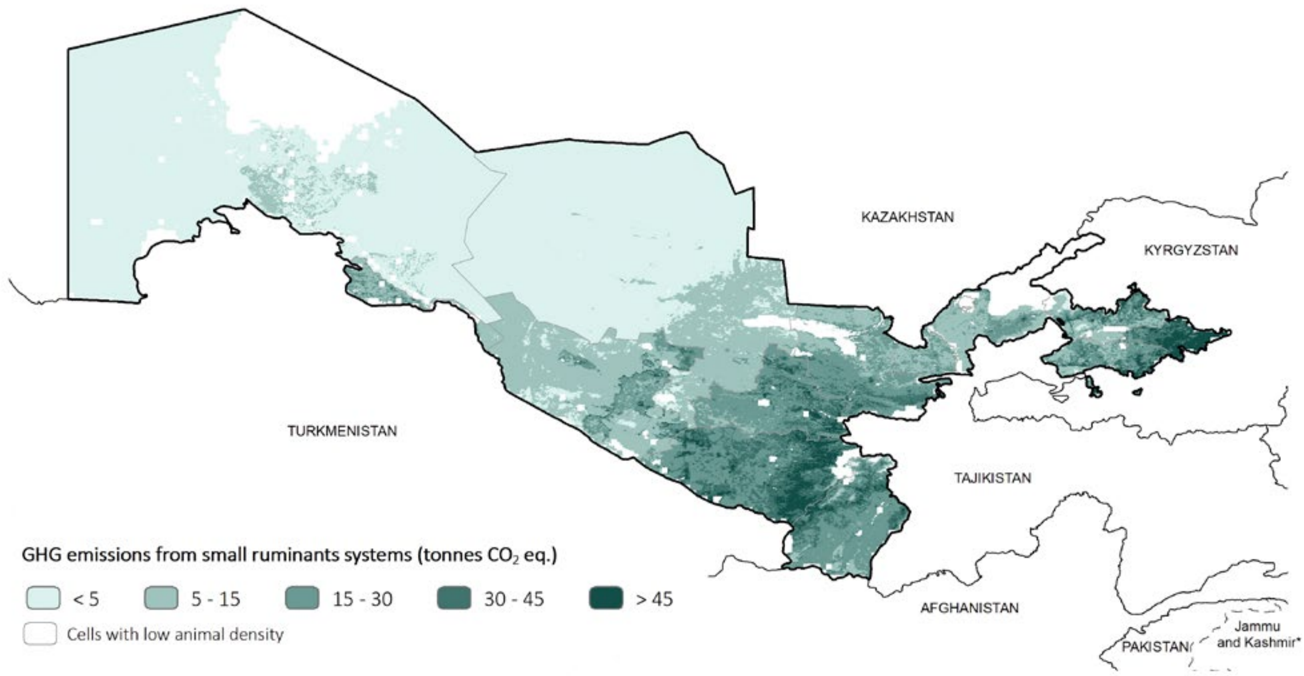
Source: UN, 2020, modified with data from Gilbert et al., 2018, and State Statistical Committee of the Republic of Uzbekistan, 2018.

Figure 5.4 Share of total emissions by emission source from small ruminant systems in Uzbekistan



Source: FAO. 2020.

Map 5.3 Regional distribution of total GHG emissions from small ruminant systems in Uzbekistan



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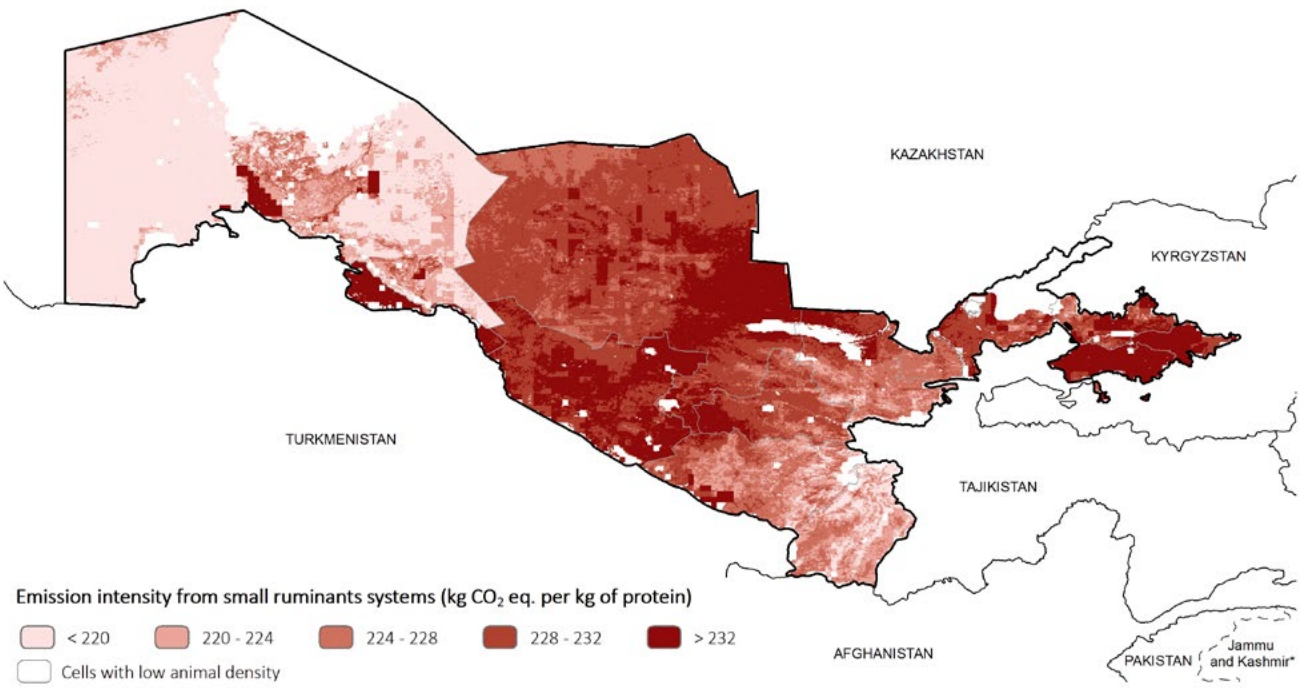
Source: UN, 2020, modified with data from Gilbert et al., 2018, and State Statistical Committee of the Republic of Uzbekistan, 2018.

Map 5.4 Regional distribution of emission intensity from small ruminant systems in Uzbekistan



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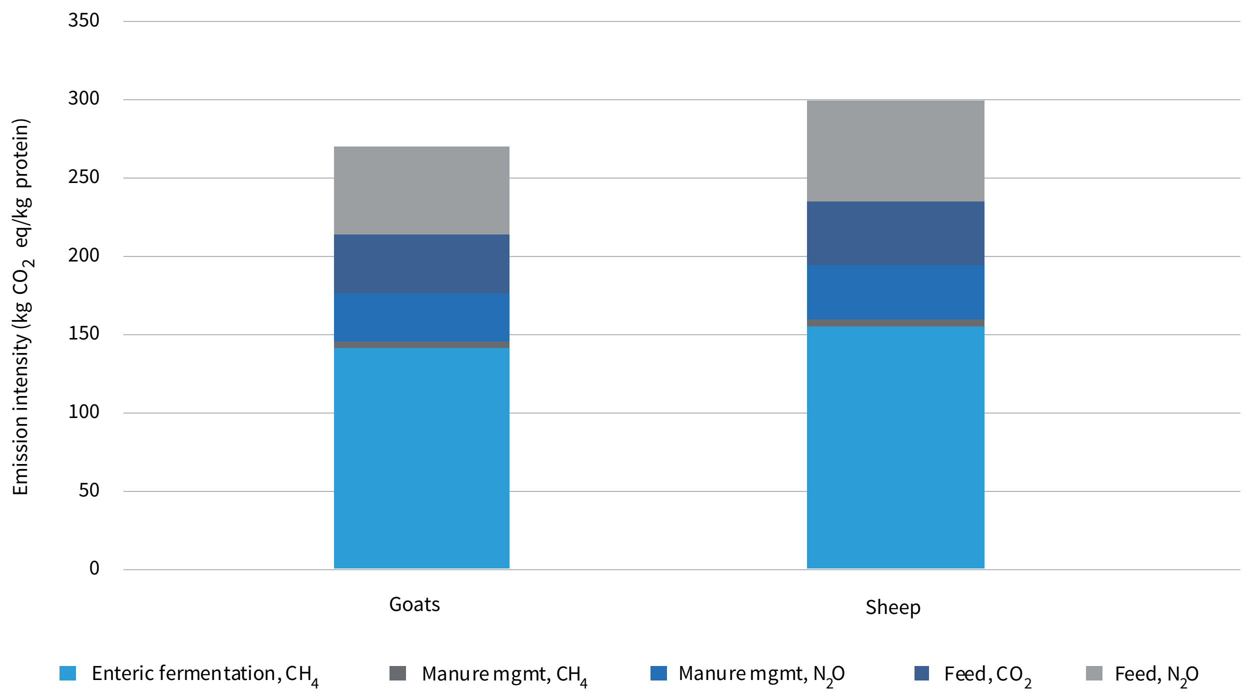
Source: UN, 2020, modified with data from Gilbert et al., 2018, and State Statistical Committee of the Republic of Uzbekistan, 2018.

Figure 5.5 Emission intensity by small ruminant systems in Uzbekistan

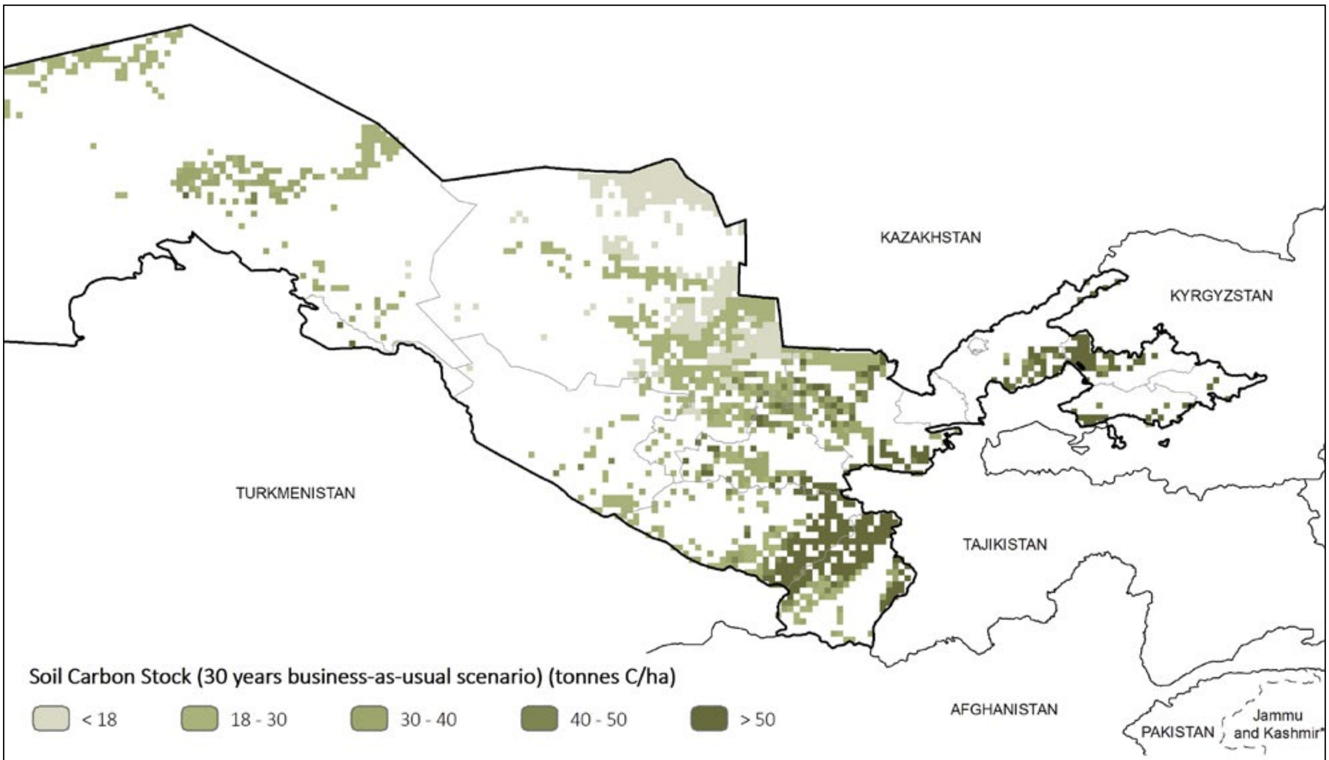


Source: FAO. 2020.

SOIL ORGANIC CARBON BASELINE

The modelling of carbon sequestration in Uzbekistan resulted in estimated average SOC stocks of 34 tonnes C/ha by 2018 (Map 5.5). Soil carbon stock follows a west to east pattern, ranging from 13 to 189 tonnes C/ha, with higher soil carbon stocks predicted in the far east of the region. The fertile lands of Fergana Valley and Andijan, in the east of the country, are the two regions with higher carbon stocks; here the high amount of carbon inputs to the soil from animal excreta (which is closely related to the high animal number) plays a crucial role in soil carbon sequestration (Map 5.6). The higher initial soil carbon in these regions, compared to other regions in the country, also contributes to a higher carbon accumulation in these unsaturated soils. It is interesting to notice that about 35 percent of the total GHG emissions from cattle production systems has been found in these same regions.

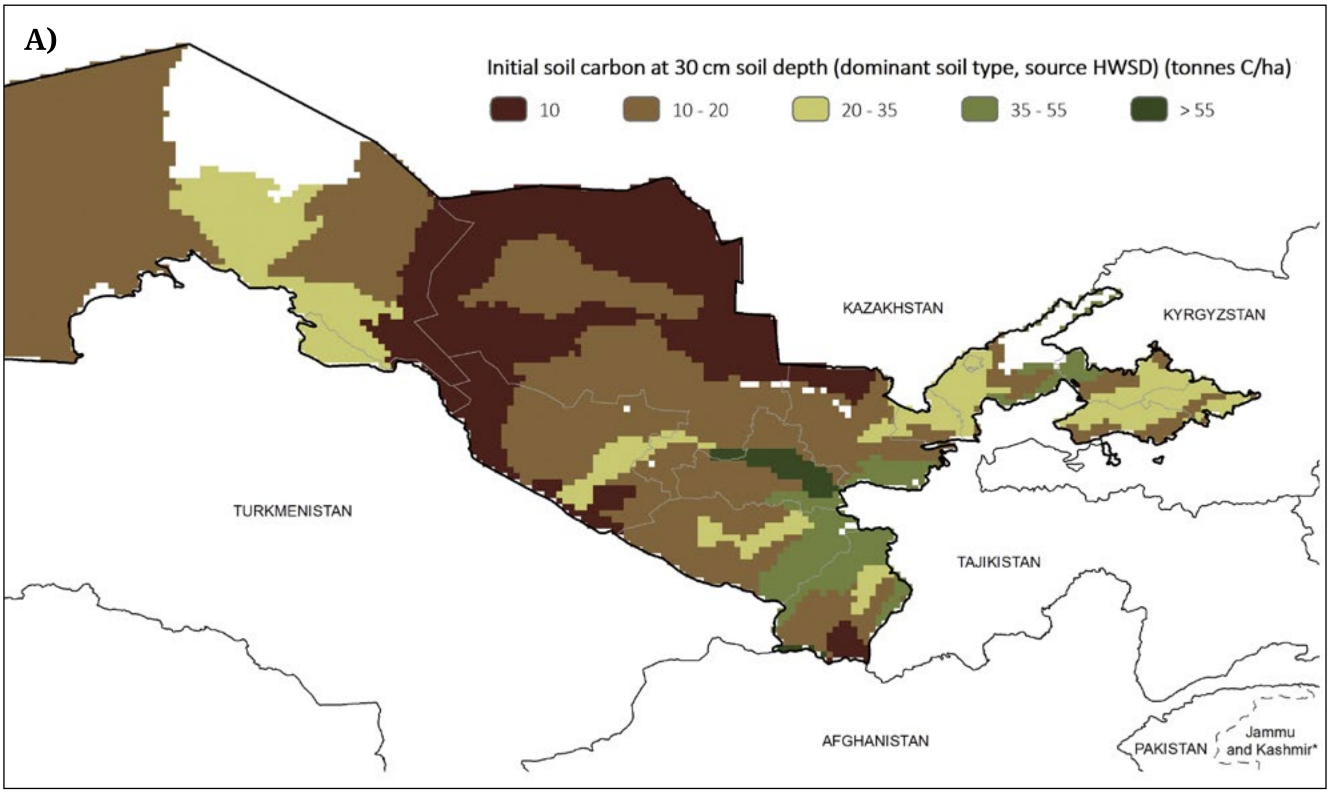
Map 5.5 Soil carbon stocks in Uzbekistan

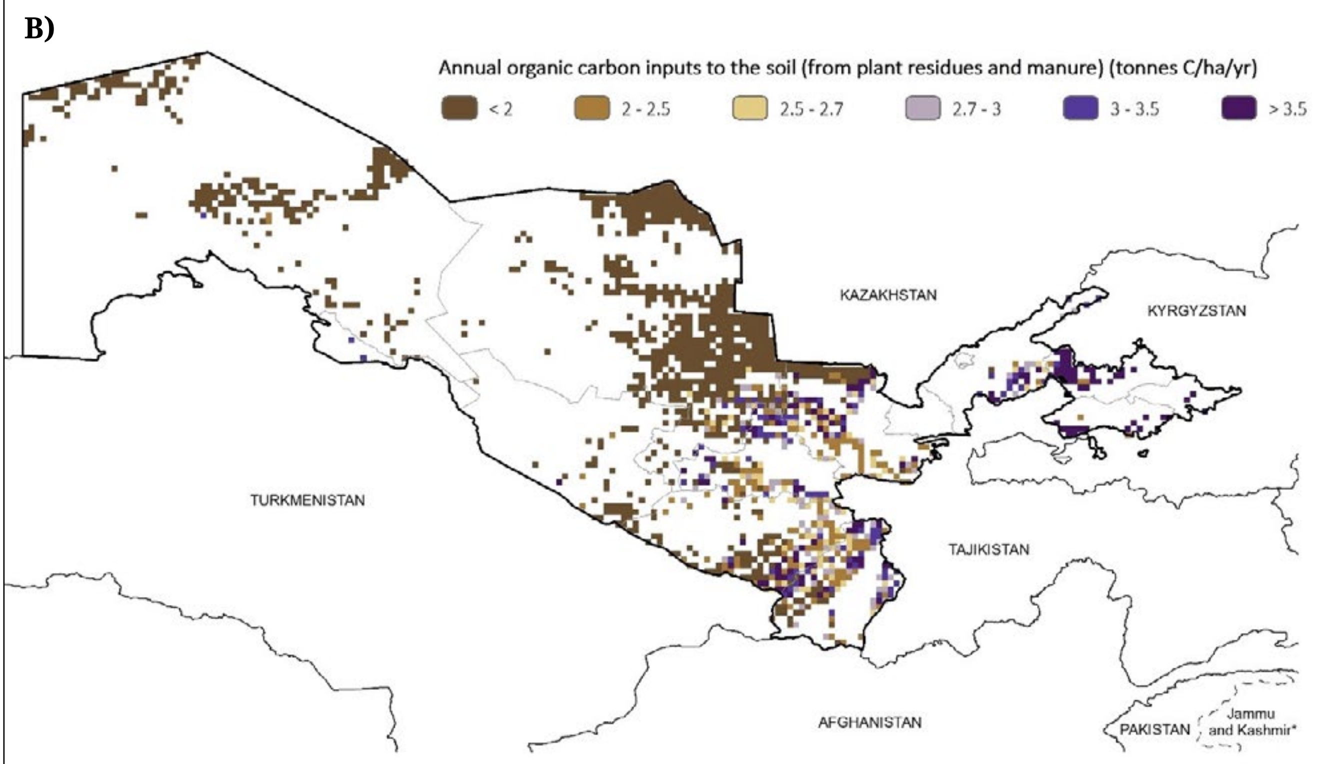


**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Coleman and Jenkinson, 1996.

Map 5.6 Input data. a) initial soil carbon at 30 cm soil depth; b) annual organic carbon inputs to the soil in Uzbekistan





**Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.*

Source: UN, 2020, modified with data from Coleman and Jenkinson, 1996.

6. Key findings and future work

KEY FINDINGS

This study found that ruminant systems in Kyrgyzstan, Tajikistan and Uzbekistan emitted 58.2 million tonnes CO_2 eq. in 2018. Within this, enteric methane is the major source of emissions representing about 72 percent of the total ruminant GHG emissions. The study also found a wide variability in emission intensities between and within countries. This wide variability is explained by the diversity of production systems, feeding practices and productivity gaps.

Reducing methane emissions is one of the most effective ways to reduce global warming in the short term, as methane is a short-lived climate pollutant (SLCP) with a life span of 12 years and a warming effect 34 times greater than carbon dioxide[3]. Therefore, reducing enteric methane emissions from ruminant systems in Central Asian countries, both in terms of absolute emissions and emission intensity, is a mitigation strategy that can deliver relatively quick gains for climate change mitigation. There is a strong correlation between animal productivity gains and enteric methane emission reduction (Gerber *et al*., 2013). In practice, this implies that the adoption of productivity-enhancing technologies and practices can provide opportunities for enteric methane mitigation, while also addressing national food security and other sustainable development goals.

Emissions related to feed production are also significant given that ruminant production is highly dependent on feed supplementation during winter. Increasing fodder and feed crop production efficiency, improving N fertilizer use efficiency, and using bio-energy fuels as an alternative to fossil fuels are some of the practices that could reduce the share of emissions related to feed production.

Grassland soils managed for grazing may or may not have suffered carbon losses relative to their native state, depending on how they have been managed. Grasslands that have been overgrazed and poorly managed are likely to be significantly depleted in soil carbon. In contrast, well-managed grasslands may have carbon stocks equal to or exceeding their original native condition (Conant *et al*., 2016). In order to define a reliable soil carbon baseline in the region, reported soil carbon stocks have been modelled by RothC to 2018. This preliminary study on soil carbon stocks found that soil carbon stocks are low in all three countries, with mean countries values from 34 tonnes C/ha in Uzbekistan, 46 tonnes C/ha in Tajikistan to 57 tonnes C/ha in Kyrgyzstan. Low carbon stocks in these regions are due to the natural conditions prone to desertification processes and are associated with climatic features – extreme seasonal temperatures and scarce precipitation. Within each country, environmental conditions, such as topography and microclimate, affected the distribution of soil carbon stocks. Despite these important aspects, this study found that the main driver for the different distribution of soil carbon, within and among regions, was the amount of carbon inputs to the soil from manure and organic amendments.

[3] Under GWP100 including climate-carbon feedback.

There is a strong correlation between animal numbers, livestock depositions and soil carbon stocks. In managed grazing land both the rate of carbon input and the rate of soil carbon loss via decomposition are impacted by the soil and management practices applied. In general, soil C stocks can be increased by: (a) increasing the rate of carbon addition to the soil, which removes CO_2 from the atmosphere, and/or (b) reducing the relative rate of loss (as CO_2) via decomposition, which reduces emissions to the atmosphere that would otherwise occur. In Central Asian countries, the first mechanism has affected the dynamics of soil carbon.

This study found that enteric methane and manure management are the predominant source of emissions from cattle systems; however, the present study also showed that regions with high GHG emissions from the cattle systems have also the highest soil carbon stocks (e.g. Issyk-Kul region in Kyrgyzstan, Fergana Valley and Andijan regions in Uzbekistan). This is mainly due to the high apportion of carbon into the soil from manure and organic amendments. Thus, in these regions, tailored practices could likely reduce GHG emissions through increased organic carbon storage.

In grasslands, such "best management practices" rely mainly on enhancing carbon inputs from plant roots and residues. This increase in carbon inputs could be achieved by managing plant biomass removal from grazing or increasing forage production through improved species, irrigation and fertilization, yielding increases in SOC stocks of as much as 10 percent (Conant *et al*., 2016). Adjusting animal stocking rates and managing plant species could also increase SOC stock of 0.07–0.3 tonnes C/ha/year on rangelands and 0.3–1.4 tonnes C/ha/year on managed pastures (Morgan *et al*., 2010).

For improving productivity and soil condition on grazing lands, there is a growing interest in intensive grazing practices employing high animal stocking rates for short durations, from a few hours to a few days, on an area of pasture, with frequent movement of animals and relatively long "rest periods" for the vegetation between grazing events. Teague *et al*. (2011) reported rates of soil C accumulation of about 3 tonnes C/ha/year in such systems compared to heavy, continuously grazed systems, and Machmuller *et al*. (2015) reported even higher C accrual rates of up to 8 tonnes C/ha/year. However, others have questioned whether rotational grazing systems are superior to well-managed continuous grazing systems (Briske *et al*., 2008), and there is an ongoing debate within the scientific community. For example, rotational grazing systems need more infrastructures and land compared to continuous grazing systems – to allow each plot to lay fallow and recover between each grazing periods.

It is to note that with increased carbon soil, carbon stocks tend toward a new equilibrium state. Thus after a few decades, carbon gains attenuate, becoming increasingly small over time (Paustian, 2014). Moreover, management changes that lead to carbon gains are potentially reversible, i.e. if management reverts to its previous condition, much or all of the gained carbon can be quickly lost.

There are opportunities to reduce emission intensity while increasing ruminant productivity in Central Asian countries. However, reducing emission intensity will lead to lower absolute emissions compared to a BAU scenario at median and long-term if the ruminant herd continues to expand. Absolute emissions can only be achieved if other practices and measures are applied in combination with productive enhancing practices and technologies. The gradual replacement of the low productive herd by more productive animals can support the transition into a reduced ruminant stock without affecting food security and the economy. Avoiding conversion and degradation of native ecosystems is another mitigation strategy. Conversely, restoration of marginal or degraded lands to grassland has a strong potential to increase soil carbon storage (Paustian *et al*., 2016). Overall, "best management practices" in grassland systems could increase soil carbon stocks by about 0.7 tonnes C/ha/year (Paustian *et al*., 2019); these mitigation strategies can be exploited and provide the opportunity to offset the absolute emissions from the sector.

DETERMINANTS OF EMISSIONS AND EMISSION INTENSITIES

A number of factors influence emissions and emission intensities from ruminant systems. In the particular case of the project participating countries, emission intensities and absolute emissions are affected by the following:

- Limited feed resources. Insufficient feed resources, both in terms of pastures and feed grains, is a common problem faced by the countries in the region. The expansion of livestock herds beyond pasture carrying capacity and low livestock mobility are some of the many causes of pasture degradation and desertification in the region (Mirzabaev *et al.*, 2016, 2019). Moreover, the focus on the two major crops (cotton and wheat), combined with the lack of crop rotation, farmland fragmentation, and limited purchase capacity of import feeds has adversely affected the availability of feed grains.

- Feed related emissions. During winter, the harsh climatic conditions, combined with overall low pasture availability, make ruminant systems in Central Asia highly dependent on feed supplementation. Feed production practices are carried out using old energy-inefficient agricultural machinery and equipment that contribute to the high CO_2 feed related emissions. Moreover, despite the elevated costs, agriculture production relies on imported synthetic fertilizers. In contrast, the use of organic fertilizers (cow manure) is low, given that most households own few animals and use manure as a source of fuel for household needs.

- Animal health. The prevalence of various animal diseases affects the performance of ruminants and affects emission intensity through "unproductive emissions" related to mortality and morbidity. Animal mortality rates are variable and relatively high (ranging between 2 to 12 percent) regardless of the system. Brucellosis, FMD, tuberculosis, echinococcosis and fascioliasis are common infectious and parasitic diseases found in these countries. Morbidity indirectly affects emission intensities through slow growth rate, reduced mature weight, poor reproductive performance and decreased milk production and weight gain.

- Reproductive efficiency. Reproductive efficiency affects emission intensity by influencing the portion of the herd in production (e.g. milked cows and young stock fattened for meat). It is also a key parameter to indicate economic performance. Improvements in reproductive performance is currently hampered by a number of factors, particularly feed availability and quality. Poor reproductive performance is manifested in a number of parameters such as low fertility rates (ranging from 65 to 82 percent in cattle systems and from 83 to 96 to in small ruminant systems), delayed time to reach puberty and age at first calving/kidding/lambing (ranging from 2.3 to 3.0 years in cattle systems and from 1.2 to 2 years in small ruminant systems).

DATA GAPS AND FUTURE WORK

Data collection is a key part of the national inventory arrangements for the compilation of Tier 2 inventories. Good practice in data collection is challenging, especially for the countries that are compilating Tier 2 inventories for the first time, and strategies to support continuous improvement over time is encouraged by the 2006 IPCC Guidelines and by the modalities, procedure and guidelines (MPG) on the Enhanced Transparency Framework (ETF) under the Paris Agreement.

Aligned with the need of establishing and improving data collection procedures, as well as directing possible research areas, we would like to list key aspects that require further improvements.

The characterization of ruminant systems is particularly challenging in the region given the shifts in political regimes and usual use of the former Soviet farming system classifications, which often do not represent the current circumstances. As emissions per animal may vary significantly depending on feeding and management practices, production system, agro-ecological or climate zone, geographical region or other factors, it is important to explicitly represent the main production systems in the GHG inventories (FAO and Global Research Alliance on Agricultural Greenhouse Gases. 2020). For the purpose of this study, the production systems were characterized based on literature research and consultation with national livestock stakeholders. This exercise led to production systems that differed between countries, but reflects the different economic circumstances, natural resource constraints, political processes and reforms taken by each country. In the future, we recommend defining ruminant production systems according to the present circumstances and unlink them from the previous Soviet farming system classification. Moreover, it would be important to link the production systems with their respective spatial allocation; this would be useful for policy intervention, extension, and animal health campaigns and further enhance the national GHG inventory.

Updated and reliable statistics on ruminant population, including information of the animal categories by age and sex at sub-national level, is a key determinant factor in establishing a robust GHG inventory. Despite the population data used in the assessment being derived from the most recent national censuses, anecdotal evidence suggests that the ruminant population might be under-reported in the official statistics, as pasture-use fees are charged per animal head, and farmers might not provide the real number of animals in the property.

Information on ruminant feed rations by season was not available in all countries. As enteric methane emissions are directly linked to the levels of feed intake and diet composition, and the fact that the local feed rations change throughout the year due to seasonality, future assessments should consider the refinement of the cattle feed rations by season, preferably characterizing the diets by animal cohort, for improved accountability of the emissions.

Official information on manure management systems (MMS) adopted by each country was not available; therefore, the MMS used in the assessment was based on national expert opinion and extrapolated from the feeding and grazing management practices adopted by the production systems. Future work, both from academia and national agencies, should be directed to collecting MMS practices, by production system and cohort, through surveys and administrative or farm records.

Given the paucity of input data used in the SOC modelling work, the assessment relied on numerous hypotheses and simplifications. As part of future planning of activities in the three countries, field measurements would be required to acquire local information to update model parameters such as soil properties, manure treatment, and application and information on the distribution of types of grassland systems and how they are managed. Process-based modelling could then be used to monitor and predict the effects of mitigation strategies on emissions and sequestration. In the long term, the direct measurements and modelled figures could form the baseline for updating the NDC and for estimating investments needed to mitigate emissions through pasture and grassland management.

7. Conclusions

Kyrgyzstan, Tajikistan and Uzbekistan have different national GHG emission profiles, but ruminant systems are important sources of emissions. The study found that ruminant systems emitted 59.2 million tonnes of CO_2 eq. in 2018 (both in terms of direct and indirect emissions), mostly released in the form of enteric methane. There is a wide variability in emission intensity levels between and within countries, which is a strong indication of the potential to increase efficiency and reduce both emission intensity and absolute emissions of ruminant systems through the adoption of best practices. Such increases in productivity, as well as making the livestock sector in the region more environmentally sustainable, can contribute to national priorities and provide cross-sector co-benefits.

Soil carbon stocks are low in all three countries, with mean country values from 34 tonnes C/ha in Uzbekistan, 46 tonnes C/ha in Tajikistan to 57 tonnes C/ha in Kyrgyzstan. Low carbon stocks are due to the natural conditions prone to desertification processes and extreme climatic conditions in these regions. However, regions with high GHG emissions from the cattle systems have also the highest soil carbon stocks. This is mainly due to the high apportion of carbon into to the soil from manure and organic amendments. Thus, in these regions, tailored practices could likely reduce GHG emissions through interventions that can increase organic carbon storage.

Improved livestock data collection and sharing, and better characterization of the production systems might benefit national and international stakeholders. In the future, special attention should be given to improving the national livestock statistics, reconsidering the definition of ruminant systems based on current practices and spatial allocation, collecting and creating a database with soil, herd and feed parameters and linking data collection with spatially explicit technologies.

Currently, despite the importance of livestock emissions in contributing to total GHG emissions in the region, the national GHG inventories of the participant countries are based on Tier 1 methods, which cannot track changes in emission intensity or link the contribution of the livestock sector to mitigation targets, since emission reductions can only be achieved if the number of animals is reduced. Moving from Tier 1 to Tier 2 based inventories is a critical step towards accounting for emissions and mitigation actions from the livestock sector (GRA and CCAFS, 2016), as GHG inventories based on Tier 2 methods portray a more accurate picture of a livestock system and its level of productivity and can capture the effects of improved management practices and technologies on emissions over time. Likewise, given the extent of grasslands in the region, a Tier 2 approach is also important in accounting for the emissions and removals from grasslands and can provide a better understanding of the mitigation opportunities from soil carbon sequestration.

Strengthening measuring, reporting and verification (MRV) systems through adoption of country-specific emission factors and use of GIS technologies can offer several benefits. At national level, improved GHG inventories can support the better estimation of emissions and support the design of more realistic targets. It can be a useful tool for informing the implementation of the NDC and tracking progress towards meeting those targets and for developing national programmes and policies for addressing climate change (e.g. Nationally Appropriate Mitigation Action, NAMAs) and meeting other sustainable development goals. Furthermore, the use of advanced inventories demonstrates greater ambition and commitment towards resolving the climate crisis and can facilitate access to climate finance.

With climate finance directed towards sectors or emission sources where quantification and monitoring of the mitigation benefits is relatively easy, mobilizing climate finance for mitigation activities in the livestock sector requires robust GHG accounting for MRV purposes, identification and prioritization of mitigation options and economic analyses to support decision-making. In sum, to advance climate finance for the livestock sector, the sector must demonstrate that mitigation practices can lead to GHG emission reductions while generating co-benefits linked with other sustainable development objectives.

This project was the first step in understanding the role of ruminants through advanced GHG accounting methods and serve as a basis for these countries to take on larger climate investment projects and catalyse climate action through sustainable livestock development. The matter now is how to move forward and incorporate the low carbon livestock framework into national priorities, attract climate finance and implement good practices at scale on the ground.

8. References

Azarov, A., Polesny, Z., Verner, V. & Darr, D. 2020. *Characteristics and Profitability of Livestock-based Farming Systems in At-Bashy, Naryn Oblast* (Issue 6) [online]. University of Central Asia. Bishkek, Kyrgyz Republic. [Cited 13 December, 2020]. https://www.ucentralasia.org/Content/Downloads/UCA-MSRI-ResearchPaper-6-Eng.pdf

Azimov, A. 2019. *Characterization of Livestock Production Systems* [online]. [Cited 13 December, 2020]. Republic of Tajikistan, Unpublished Report. University of Central Asia. https://www.ucentralasia.org/Research/MSRI/EN

Briske, D.D., Derner, J.D., Brown, J.R., Fuhlendorf, S.D., Teague, W.R., Havstad, K.M., Gillen, R.L., Ash, A.J. & Willms, W.D. 2008. Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence. *Rangeland Ecology & Management*, 61(1): 3–17. (also available at https://linkinghub.elsevier.com/retrieve/pii/S1550742408500078).

Botman, E. 2009. *Forest rehabilitation in the Republic of Uzbekistan* [online]. Tashkent. [Cited 13 December 2020].
https://www.iufro.org/download/file/7408/5123/Uzekistan_pdf/

Broka, S., Giertz, Å., Christensen, G. N., Hanif, C. W., Rasmussen, D. L. & Rubaiza, R. 2016. Kyrgyz Republic Agricultural sector risk assessment. Agriculture global practice technical assistance paper. In: *The World Bank* [online]. Washington DC.[Cited 13 December 2020].
http://documents.worldbank.org/curated/en/744171467997560716/Kyrgyz-Republic-Agricultural-sector-risk-assessment

Broka, S., Giertz, Å., Christensen, G. N., Hanif, C. W. & Rasmussen, D. L. 2016. Tajikistan Agricultural sector risk assessment. Agriculture global practice technical assistance paper. In: *The World Bank* [online]. Washington DC. [Cited 13 December 2020].http://documents.worldbank.org/curated/en/395161468196164557/Tajikistan-Agricultural-sector-risk-assessment

Coleman, K. & Jenkinson, D.S. 1996. RothC-26.3 - A Model for the turnover of carbon in soil. In D.S. Powlson, P. Smith & J.U. Smith, eds. *Evaluation of Soil Organic Matter Models,* pp. 237–246. Berlin, Heidelberg, Springer Berlin Heidelberg. (also available at http://link.springer.com/10.1007/978-3-642-61094-3_17)

Conant, R.T., Cerri, C.E.P., Osborne, B.B. & Paustian, K. 2017. Grassland management impacts on soil carbon stocks: a new synthesis. *Ecological Applications*, 27(2): 662–668 [online]. [Cited 13 December, 2020]. https://doi.org/10.1002/eap.1473

Deniskova, T., Dotsev, A., Lushihina, E., Shakhin, A., Kunz, E., Medugorac, I., Reyer, H., Wimmers, K., Khayatzadeh, N., Sölkner, J., Sermyagin, A., Zhunushev, A., Brem, G. & Zinovieva, N. 2019. Population Structure and Genetic Diversity of Sheep Breeds in the Kyrgyzstan. *Frontiers in Genetics*, 10: 1311 [online]. [Cited 13 December 2020]. https://doi.org/10.3389/fgene.2019.01311

FAO. 2018. *FAOSTAT* [online]. Rome. [Cited 6 February 2021].
http://www.fao.org/faostat/en/#data

FAO. 2020. *The Global Livestock Environmental Assessment Model–GLEAM* [online]. Rome. [Cited 6 February, 2021]. http://www.fao.org/gleam/en/

FAO & Global Research Alliance on Agricultural Greenhouse Gases. 2020. *Livestock Activity Data Guidance (L-ADG): Methods and guidance on compilation of activity data for Tier 2 livestock GHG inventories* [online]. [Cited 13 December, 2020].
https://doi.org/10.4060/ca7510en.

FAO, IIASA, ISRIC, ISS-CAS & JRC. 2012. *Harmonized World Soil Database*. Rome, FAO. 43 pp. (also available at www.fao.org/3/aq361e/aq361e.pdf)

Farrington, J. D. 2005. De-Development in Eastern Kyrgyzstan and Persistence of Semi-nomadic Livestock Herding. *Nomadic Peoples*, 9(1/2, Special Issue: Pastoralists): 171–197 [online]. [Cited 13 December, 2020]. https://www.jstor.org/stable/43123753

GEF. 2019. Sustainable Forest and Rangelands Management in the Dryland Ecosystems of Uzbekistan [online]. Tashkent. [Cited 13 December 2020]. https://www.thegef.org/sites/default/files/web-documents/10367_LD_PIF.pdf

Gerber, P.J., Steinfeld, H. B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G., eds. 2013. *Tackling climate change though livestock: a global assessment of emission and mitigation opportunities.* Rome, FAO. 115 pp.

Gilbert, M., Nicolas, G., Cinardi, C., Van Boeckel, T.P., Vanwambeke, S.O., Wint, G.R.W. & Robinson, T.P. 2018. *Global distribution data for cattle, buffaloes, horses, sheep, goats, pigs, chickens and ducks in 2010.* Scientific Data 5: 180227 [online]. [Cited 21 April 2021]. https://doi.org/10.1038/sdata.2018.227

GRA & CCAFS. 2016. *Livestock development and climate change: The benefits of advanced greenhouse gas inventories* [online]. [Cited 13 December, 2020]. Global Research Alliance on Agricultural Greenhouse Gases. (also available at https://cgspace.cgiar.org/bitstream/handle/10568/76520/Inventory%20Brochure_Final.pdf).

Harris, I., P.D. Jones, T.J. Osborn & D.H. Lister. 2014. Updated high-resolution grids of monthly climatic observations - the CRU TS3.10 Dataset. *International Journal of Climatology* 34(3): 623-642 [online]. [Cited 19 February, 2021]. doi:10.1002/joc.371

ICARDA. 2003. ICARDA Annual Report 2002. Aleppo, Syria: International Center for Agricultural Research in the Dry Areas In: *ICARDA* [online]. [Cited 13 December, 2020]. https://www.icarda.org/publications/6285/icarda-annual-report-2002

IFAD. 2011. *President's report Proposed grant to the Republic of Tajikistan for the Livestock and Pasture Development Project* (Issue E.B. 2011/102/R.23) [online]. Rome. [Cited 13 December 2020]. https://webapps.ifad.org/members/eb/102/docs/EB-2011-102-R-23.pdf

IFAD. 2013. *Livestock and market development programme design completion report. Near East, North Africa and Europe Division Programme Management Department* [online]. Rome. [Cited 13 December 2020]. https://www.ifad.org/documents/38711624/40049138/LMDPII%20_%20PDR%20%20_0000-304-632.pdf/13af623b-51eb-47e7-a48f-51e5e2d660a2?1517974723308

IFAD. 2015a. *Dairy Value Chain Development Programme, Uzbekistan. Design completion report* (Issues 3762-UZ) [online]. Rome. [Cited 13 December 2020]. https://webapps.ifad.org/members/eb/115/docs/EB-2015-115-R-14-Project-design-report.pdf

IFAD. 2015b. *Livestock and Pasture Development Project-II. Detailed design report* (Issues 3820-TJ) [online]. Rome. [Cited 13 December 2020]. https://www.gtai.de/:PRO201711305002

IFAD. 2016. *Kyrgyz Republic Access to Markets Project Final Project Design Report* (Issue 21) [online]. Rome. [Cited 13 December 2020]. https://webapps.ifad.org/members/eb/119/docs/EB-2016-119-R-28-Project-design-report.pdf

IFAD. 2018. Kyrgyz Republic: *Country strategic opportunities programme 2018-2022* (Issue April) [online]. Rome. [Cited 13 December 2020]. https://webapps.ifad.org/members/eb/123/docs/EB-2018-123-R-7.pdf?attach=1

IFAD. 2020. *Dairy Value Chains Development Program, Uzbekistan. Partial Supervision Report* (Issues 5524-UZ) [online]. Rome. [Cited 13 December 2020]. https://www.ifad.org/documents/38711624/40089498/Uzbekistan%201100001714%20DVCDP%20Supervision%20Report%20October%202020/5343d92e-d5cd-c2f4-06fe-3bffcda1810f

Iñiguez, L., Mueller, J.P., Ombayev, A., Aryngaziyev, S., Ajibekov, A., Yusupov, S., Ibragimov, A., Suleimenov, M. & Hilali, M.E.-D. 2014. Characterization of mohair and cashmere in regions of Kazakhstan, Kyrgyzstan and Uzbekistan. *Small Ruminant Research*, 120(2–3): 209–218 [online]. [Cited 13 December, 2020]. https://doi.org/10.1016/j.smallrumres.2014.05.004

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* [online]. Geneva. [Cited 6 February, 2021]. https://www.ipcc.ch/report/ar5/syr

JICA. 2013. *Kyrgyz Republic Data Collection Survey on Dairy Industry Final Report* [online]. Bishkek. [Cited 13 December 2020]. https://openjicareport.jica.go.jp/pdf/12146957.pdf

JICA. 2017. *The Data Collection Survey on Agriculture Sector in Republic of Uzbekistan* (Issues 17–016) [online]. Tashkent. [Cited 13 December 2020]. https://openjicareport.jica.go.jp/pdf/1000032445.pdf

Kerven, C., McGregor, B. & Toigonbaev, S. 2009. Cashmere-producing goats in Central Asia and Afghanistan. Animal Genetic Resources Information, 45: 15–27 [online]. [Cited 13 December 2020]. https://doi.org/10.1017/S1014233909990289

Kerven, C., Steimann, B., Ashley, L., Dear, C. & Rahim, I. 2011. *Pastoralism and farming in Central Asia's mountains: a research review* [online]. [Cited 13 December, 2020]. https://www.zora.uzh.ch/id/eprint/52730

Kurbanova, B. 2012. Constraints and Barriers to Better Land Stewardship: Analysis of PRAs in Tajikistan. *In V. Squires, ed. Rangeland Stewardship in Central Asia: Balancing Improved Livelihoods, Biodiversity Conservation and Land Protection,* pp. 129–161. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-94-007-5367-9_7).

Lal, R. 2004. Carbon sequestration in soils of central Asia. *Land Degradation & Development,* 15(6): 563–572 [online]. [Cited 1 March 2021]. http://doi.wiley.com/10.1002/ldr.624

Lerman, Z. & Sedik, D. 2009. *Sources of Agricultural Productivity Growth in Central Asia: The Case of Tajikistan and Uzbekistan.* Budapest, FAO. 18 pp. (also available at http://www.fao.org/3/a-aq337e.pdf).

Lushikhina, E. M. 2013. *Sheep Breed Resources of Kyrgyzstan. Sbornik Naychnykh Trudov Vserossiiskogo Nauchno-Issledovatel`skogo Instituta Ovtsevodstva i Kozovodstva* [online]. Stavropol. [Cited 13 December 2020]. https://s3-eu-west-1.amazonaws.com/sniizhk/2013-1/014.pdf

Machmuller, M.B., Kramer, M.G., Cyle, T.K., Hill, N., Hancock, D. & Thompson, A. 2015. Emerging land use practices rapidly increase soil organic matter. *Nature Communications,* 6(1): 6995 [online]. [Cited 13 December, 2020]. https://doi.org/10.1038/ncomms7995

Mirzabaev, A., Ahmed, M., Werner, J., Pender, J. & Louhaichi, M. 2016. Rangelands of Central Asia: challenges and opportunities. *Journal of Arid Land,* 8(1): 93–108 [online]. [13 December 2020]. https://doi.org/10.1007/s40333-015-0057-5

Mirzabaev, A., Wu, J., Evans, J., García-Oliva, F., Hussein, I. A. G., Iqbal, M. H., Kimutai, J., Knowles, T., Meza, F., Nedjraoui, D., Tena, F., Türkeş, M., Vázquez, R. G. & Weltz, M. 2019. Desertification. In J. M. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M., eds. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems,* pp. 249–307. (also available at https://catalogue.unccd.int/1244_Desertification_06_Chapter-3.pdf).

Mogilevskii, R., Abdrazakova, N., Bolotbekova, A., Chalbasova, S., Dzhumaeva, S., & Tilekeyev, K. 2017. *The outcomes of 25 years of agricultural reforms in Kyrgyzstan.* Discussion Paper No. 162 [online]. Halle (Saale), Germany. [Cited 13 December 2020]. http://nbn-resolving.de/urn:nbn:de:gbv:3:2-69129%0A

Morgan, J.A., Follett, R.F., Allen, L.H., Del Grosso, S., Derner, J.D., Dijkstra, F., Franzluebbers, A., Fry, R., Paustian, K. & Schoeneberger, M.M. 2010. Carbon sequestration in agricultural lands of the United States. *Journal of Soil and Water Conservation,* 65(1): 6A-13A [online]. [Cited 13 December, 2020]. https://doi.org/10.2489/jswc.65.1.6A

Mukimov, T. 2019. Characterization of Livestock Production Systems, Republic of Uzbekistan. Unpublished Report. In: *University of Central Asia* [online]. [Cited 13 December, 2020]. https://www.ucentralasia.org/Research/MSRI/EN)

National Communication of the K.R. 2017. *Third National Communication of the Kyrgyz Republic under The U.N. Framework Convention on Climate Change* [online]. Bishkek. [Cited 13 December 2020]. https://unfccc.int/sites/default/files/resource/NC3_Kyrgyzstan_English_24Jan2017.pdf

National Communication of the R.T. 2014. *Third National Communication of the Republic of Tajikistan under the United Nations Framework Convention on Climate Change.* [online]. Dushanbe, Tajikistan. [Cited 13 December 2020]. https://unfccc.int/resource/docs/natc/tjknc3_eng.pdf

National Communication of the R.U. 2016. *The Third National Communication of the Republic of Uzbekistan under the U.N. Framework Convention on Climate Change* [online]. Tashkent, Republic of Uzbekistan. [Cited 13 December 2020]. https://unfccc.int/sites/default/files/resource/TNC%20of%20Uzbekistan%20under%20UNFCCC_english_n.pdf

NSC (National Statistic Committee) of the KR. 2019. Agriculture of the Kyrgyz republic in 2014-2018. In: *National Statistical Committee of the KR* [online]. Bishkek. [Cited 13 September 2020] http://stat.kg/en/publications/

Paustian, K. 2014. Soil: Carbon Sequestration in Agricultural Systems. *Encyclopedia of Agriculture and Food Systems*, 5:140–152.

Paustian, K., Larson, E., Kent, J., Marx, E. & Swan, A. 2019. Soil C Sequestration as a Biological Negative Emission Strategy. *Frontiers in Climate*, 1:8.

Paustian, K., Lehmann, J., Ogle, S., Reay, D., Robertson, G.P. & Smith, P. 2016. Climate-smart soils. *Nature*, 532:49–57.

Robinson, S. 2016. Land Degradation in Central Asia: Evidence, Perception and Policy. *In. The End of Desertification? Disputing Environmental Change in the Drylands* [online]. [Cited 13 December, 2020]. https://doi.org/10.1007/978-3-642-16014-1_17

Robinson, Sarah, Safaraliev, G. & Muzofirshoev, N. 2010. *Carrying capacity of pasture and fodder resources in the Tajik Pamirs. A Report for the FAO.* 59 pp. Rome, FAO.

Ruzibaev, N. R. 2019. Some Economic and Useful Traits of Meat and Wool Sheep Breeds in Uzbekistan. *Agricultural Journal*, 12(3): 6 [online]. [Cited 13 December 2020]. https://doi.org/10.25930/0372-3054/011.3.12.2019

Salimova, N. 2018. Problems and Prospects of Livestock in Uzbekistan. *Peer Reviewed Journal of Forensic & Genetic Sciences*, 2(3): 129–133 [online]. [Cited 13 December 2020]. https://doi.org/10.32474/prjfgs.2018.02.000139

Sati, V.P. & Vangchhia, L. 2017. Food Security and Poverty. *A Sustainable Livelihood Approach to Poverty Reduction*, pp. 81–92. SpringerBriefs in Environmental Science. Cham, Springer International Publishing. (also available at http://link.springer.com/10.1007/978-3-319-45623-2_8).

Schillhorn van Veen, T. W. 1995. *The Kyrgyz Sheep Herders at a Crossroads. Pastoral Development Network Series Paper* 38d [online]. London, UK. [Cited 13 December, 2020]. https://cdn.odi.org/media/documents/5415.pdf

Sedik, D. 2012. The Feed-Livestock Nexus: Livestock Development Policy in Tajikistan. In V. Squires, ed. *Rangeland Stewardship in Central Asia: Balancing Improved Livelihoods, Biodiversity Conservation and Land Protection,* pp. 189–212. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-94-007-5367-9)

Shaumarov, M., Toderich, K. N., Shuyskaya, E. V, Ismail, S., Radjabov, T. F. & Kozan, O. 2012. Participatory Management of Desert Rangelands to Improve Food Security and Sustain the Natural Resource Base in Uzbekistan. In V. Squires, ed. *Rangeland Stewardship in Central Asia: Balancing Improved Livelihoods, Biodiversity Conservation and Land Protection,* pp. 381–404. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-94-007-5367-9_16).

Squires, Victor. 2012. Governance and the Role of Institutions in Sustainable Development in the Central Asian Region. In V. Squires, ed. *Rangeland Stewardship in Central Asia: Balancing Improved Livelihoods, Biodiversity Conservation and Land Protection, pp.* 275–303. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-94-007-5367-9).

Squires, V. & Feng, H. 2017. Rangeland and Grassland in the Region of Former Soviet Union: Future Implications for Silk Road Countries. In V. Squires, Z. H. Shang & A. Ariapour, eds. *Rangelands along the Silk Road: Transformative Adaptation under Climate and Global Change*, pp. 283–297. Environmental research advances. New York, Nova Science Publishers, Inc.

State Statistical Committee of the Republic of Uzbekistan. 2018. Agriculture, Forestry and Fishing in Uzbekistan. In*: stat.uz* [online]. [Cited 9 October 2020]. https://stat.uz/en/

State Statistical Committee of the Republic of Uzbekistan. 2020. Uzbekistan in Figures. In: *stat.uz* [online]. Tashkent. [Cited 9 October 2020]. https://stat.uz/en/

Statistical Agency under President of the Republic of Tajikistan (SAPRT). 2020. Food Security and Poverty. In: *TAJSTAT* [online]. Dushanbe. [Cited 13 December 2020]. https://www.stat.tj/en/catalog

Strong, P. J. H. & Squires, V. 2012. Rangeland-Based Livestock: A Vital Subsector Under Threat in Tajikistan. In V. Squires, ed*. Rangeland Stewardship in Central Asia: Balancing Improved Livelihoods, Biodiversity Conservation and Land Protection,* pp. 213–235. Dordrecht, Springer Netherlands. (also available at http://link.springer.com/10.1007/978-94-007-5367-9).

Suleimenov, M. & Oram, P. 2000. Trends in feed, livestock production, and rangelands during the transition period in three Central Asian countries. *Food Policy*, 25(6): 681–700 [online]. [Cited 13 December 2021]. https://www.sciencedirect.com/science/article/pii/S0306919200000373#aep-bibliography-id25

Sutton, W. R., Srivastava, J. P., Neumann, J. E., Droogers, P. & Boehlert, B. 2013. *Reducing the Vulnerability of Uzbekistan's Agricultural Systems to Climate Change: Impact Assessment and Adaptation Options.* The World Bank. (also available at http://elibrary.worldbank.org/doi/book/10.1596/978-1-4648-0000-9)

Teague, W.R., Dowhower, S.L., Baker, S.A., Haile, N., DeLaune, P.B. & Conover, D.M. 2011. Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems & Environment,* 141(3–4): 310–322 [online]. [Cited 13 December, 2020]. https://doi.org/10.1016/j.agee.2011.03.009

Tilekeyev, K., Mogilevskii, R., Bolotbekova, A. & Dzhumaeva, S. 2017. Sheep Meat Production Value Chains in the Kyrgyz Republic and Export Capacity to the EAEU Member States. *SSRN Electronic Journal*, Working Paper No. 36, 2016 [online]. [Cited 9 October 2020]. https://doi.org/10.2139/ssrn.2946728

UN. 2020. Map of the World. In: *UN* [online]. [Cited 1 January 2021]. un.org/geospatial/file/3420/download?token=bZe9T8I9

World Bank. 2007. *Kyrgyz Republic Livestock Sector Review: Embracing the New Challenges* [online]. Washington DC. [Cited 9 October 2020]. https://openknowledge.worldbank.org/handle/10986/8033

World Bank. 2012. *Priorities for Sustainable Growth: A strategy for Agriculture Sector Development in Tajikistan Technical Annex 3. Livestock Sector Review. Public expenditure review* [online]. Washington DC. [Cited 9 October 2020]. https://openknowledge.worldbank.org/handle/10986/12408

World Bank. 2017. *Livestock Sector Development Project* (Issue PAD 2275) [online]. Washington, DC. [Cited 25 January, 2020]. http://documents1.worldbank.org/curated/ar/128331504722189404/Project-Appraisal-Document-PAD-P153613-2017-06-02-10-39-06062017.docx

Yu.B. Yusupov, Z. Lerman, A.S. Chertovitskiy & Akbarov, O. 2010. *Livestock Production in Uzbekistan: Current state, Challenges and Prospects* [online]. [Cited 13 December 2020]. http://rgdoi.net/10.13140/RG.2.1.4234.7043

Zhumanova, M. 2019. *Characterization of Livestock Production System, Kyrgyz Republic.* Unpublished Report. In: *University of Central Asia* [online]. [Cited 13 December, 2020]. https://www.ucentralasia.org/Research/MSRI/EN

Zhumanova, M., Wrage-Mönnig, N. & Darr, D. 2016. Farmers' Decision-making and Land Use Changes in Kyrgyz Agropastoral Systems. *Mountain Research and Development,* 36(4): 506–517 [online]. [Cited 13 December 2021]. http://www.bioone.org/doi/10.1659/MRD-JOURNAL-D-16-00030.1

Zorya, S., Djanibekov, N. & Petrick, M. 2019. *Farm Restructuring in Uzbekistan: How Did It Go and What is Next?* [online]. Washington, DC. [Cited 13 December 2020]. http://documents.worldbank.org/curated/en/686761549308557243/pdf/134322-WP-P162303-PUBLIC-Report-Farm-Restructuring-in-Uzbekistan-eng.pdf

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