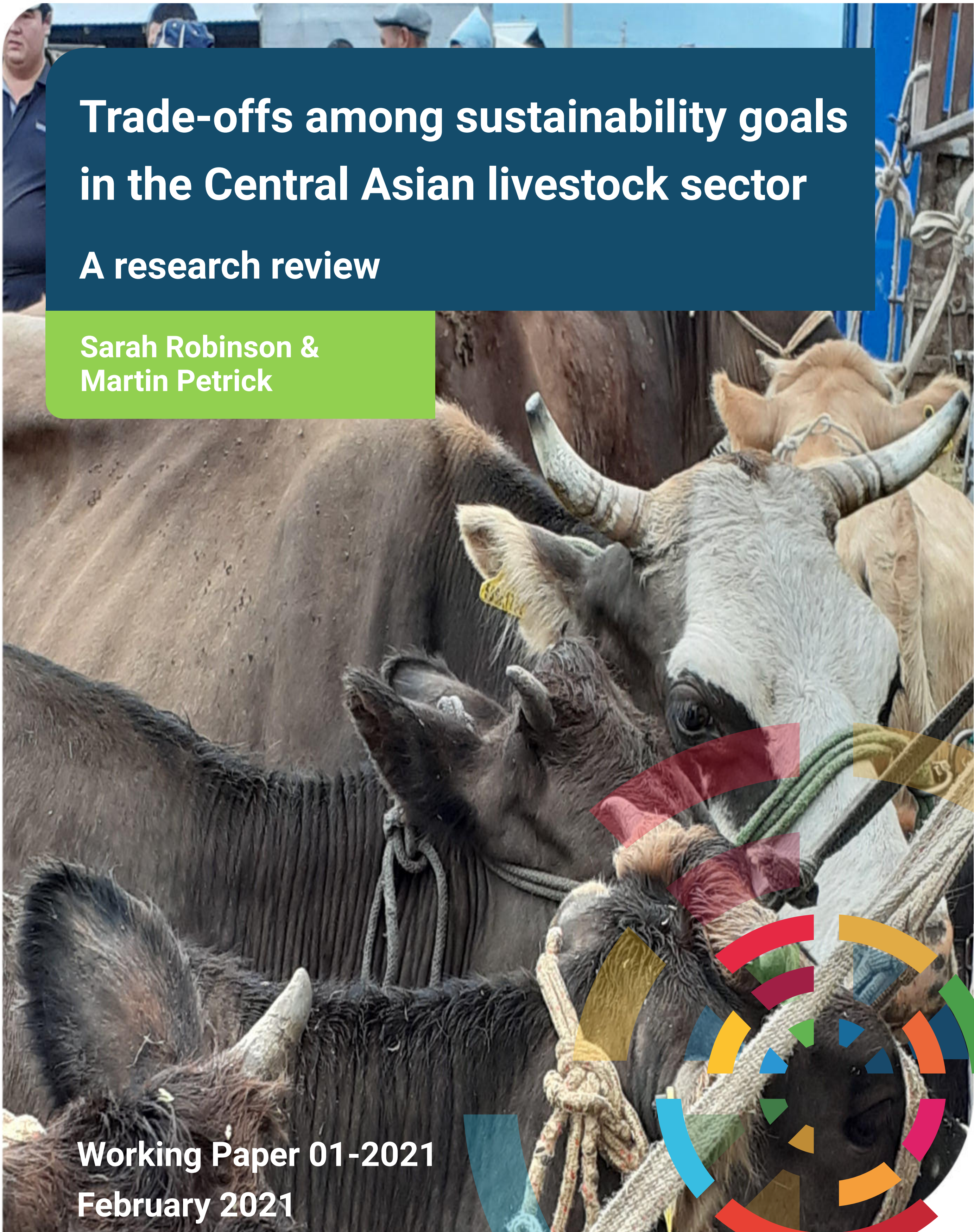

Trade-offs among sustainability goals in the Central Asian livestock sector

A research review

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Working Paper 01-2021
February 2021

DAAD The SDG[nexus] Network is supported by the DAAD with funds of the German Federal Ministry for Economic Cooperation (BMZ)

Abstract

The SDG^nexus Network (SDGNN) establishes a common research framework for the Sustainable Development Goals (SDGs), supporting research, networking and capacity building of scientists in Latin America and Central Asia. This report examines the livestock sector in Central Asia as one of the main research areas of the SDGNN. Based on a comprehensive review of the literature to date, we distinguish five major SDG trade-offs that we expect in three key areas:

1. Agricultural commercialisation may exclude smallholder farmers, and rising incomes may lead to dietary change with negative health outcomes, implying a trade-off between poverty reduction and zero hunger (SDGs 1 & 2) on the one hand and decent work and economic growth (SDGs 8 & 9) on the other.
2. More productive small livestock farmers may degrade environmental resources, and more diverse and nutritious diets through meat and milk products may overexploit feeding resources, implying a trade-off between poverty reduction and zero hunger (SDGs 1 & 2) on the one hand and water availability (SDG 6), life on land (SDG 15) and climate action (SDG 13) on the other.
3. At a sectoral scale, economic growth may put pressure on key resources for livestock husbandry, implying a trade-off between economic growth (SDGs 8 & 9) on the one hand and water availability (SDG 6), life on land (SDG 15) and climate action (SDG 13) on the other.

We investigate the potential synergies and trade-offs within eight topical sections: farm restructuring and land reform; sustainable grazing systems; fodder production and irrigation; livestock species, genetic improvement and animal health; value chain development; human diet and health; livestock production and climate change; and services and policies for agriculture. We identify key research gaps in each area and thus present a research agenda for the SDG Nexus project in the area of livestock husbandry in Central Asia.

Keywords: livestock production, natural resources, SDGs, Central Asia.

JEL codes: P28, Q12, Q56.

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Acronyms and abbreviations

AI	Artificial Insemination
AOI	Agriculture Orientation Index
ASF	Animal Source Food
CACILM	Central Asian Countries Initiative for Land Management
CISFTA	Commonwealth of Independent States Free Trade Area
CIS	Commonwealth of Independent States
CPRM	Common Property Resource Management
CSE	Consumer Support Estimate
DALY	Disability Adjusted Life Year
DES	Dietary Energy Supply
EAEU	Eurasian Economic Union
ECA	Europe and Central Asia
ELD	Economics of Land Degradation
FAO	Food and Agriculture Organisation
FIES	Food Insecurity Experience Scale
FDI	Foreign Direct Investment
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GHG	Green House Gas
GIZ	German Agency for International Cooperation
GSP	Generalised Scheme of Preferences
GSSE	General Services Support Estimate
HH	Household
HDP	Human Digestible Protein
IF	Individual Farm
IFAD	International Fund for Agricultural Development
LU	Livestock Unit
LUCC	Land Use and Cover Change
LUR	Land Use Ratio
MCO	Micro-Credit Organisation
MPS	Market Price Support
NAP	National Action Plan
NCD	Non Communicable Disease
NDVI	Normalised Difference Vegetation Index
NRA	Nominal Rate of Assistance
NRM	Natural Resource Management
NPP	Net Primary Productivity
OECD	Organisation for Economic Cooperation and Development
PoU	Prevalence of Undernourishment
PPRV	Peste des Petits Ruminants Virus
PSE	Producer Support Estimate
PUA	Pasture Users Association
RAS	Rural Advisory Services
SDG	Sustainable Development Goal
SDGNN	Sustainable Development Goals nexus Network
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
TBT	Technical Barriers to Trade
TRQ	Tariff Rate Quota
TSE	Total Support Estimate
UNCCD	United Convention on Combating Desertification
WOCAT	World Overview of Conservation Approaches and Technologies
WUA	Water Users Association

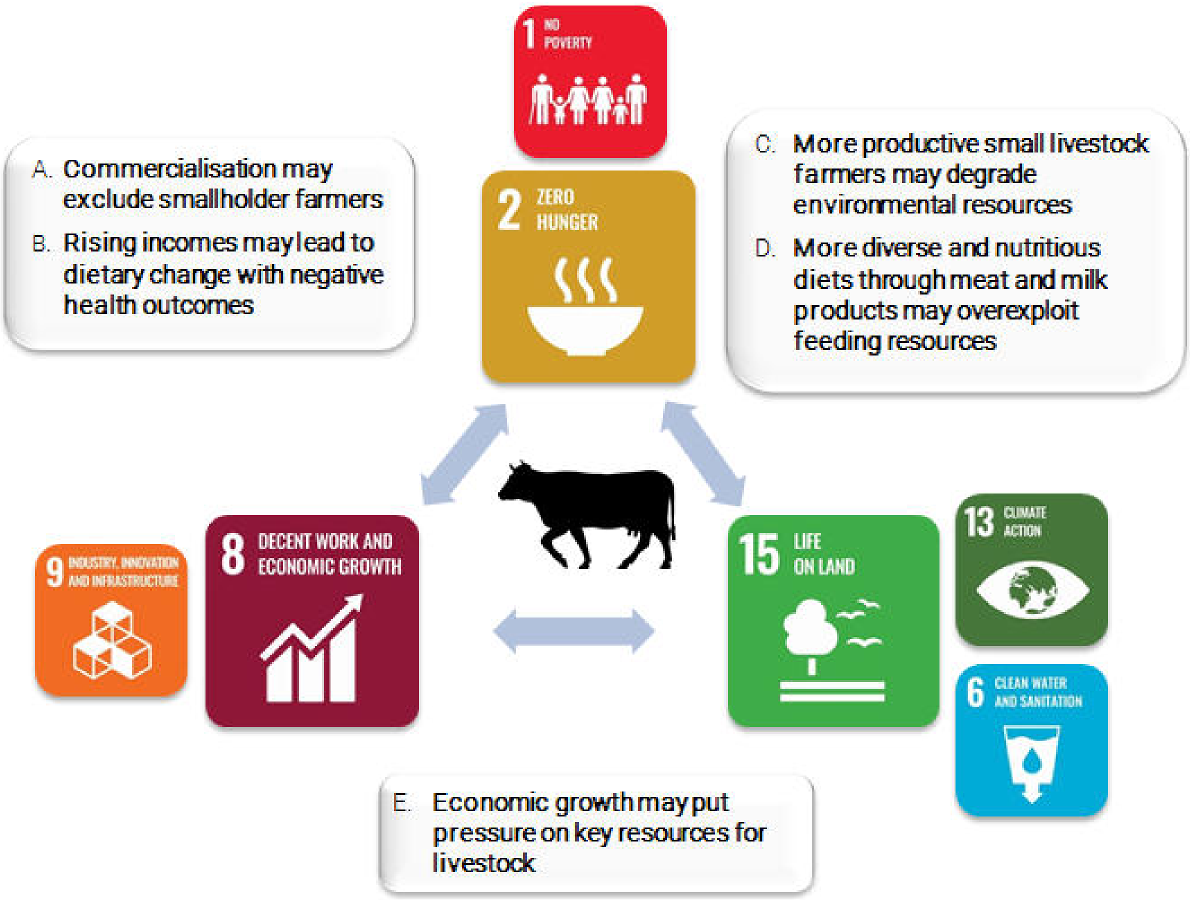
Executive summary

The SDG Nexus

The SDG^{nexus} Network (SDGNN) establishes a common research framework for the Sustainable Development Goals (SDGs), supporting research, networking and capacity building of scientists in Latin America and Central Asia. The network takes a nexus approach because progress towards SDGs cannot be understood in isolation. In any given area, progress in some pairs or groups of SDGs is synergistic, whilst others are antagonistic, exhibiting trade-offs with each other.

The SDG^{nexus} Network research programme covers five major research areas: food systems; water; urban and rural areas; natural resources; and SDG monitoring. This report addresses the topic of food systems and focusses on the livestock sector in Central Asia. In the following, we distinguish five major SDG trade-offs (A-E) that we expect in three key areas (Figure I):

Figure I. The livestock nexus in Central Asia: relevant SDGs and their trade-offs



Source: authors.

Between poverty reduction and zero hunger (SDGs 1 & 2) on the one hand and decent work and economic growth (SDGs 8 & 9) on the other. There may be trade- offs between the development of larger farming units, more able to provide quality and quantity of raw livestock products to support domestic processing industries and export, and productivity gains and value chain integration amongst smaller farms, with advantages for poverty reduction, rural employment and food security (trade-off A). At the national level, increasing growth and incomes may be associated with dietary modification, obesity and increasing prevalence of non-communicable diseases (trade-off B).

Between poverty reduction zero hunger (SDGs 1 & 2) on the one hand and water availability (SDG 6), life on land (SDG 15) and climate action (SDG 13) on the other. SDG target 2.3 suggests raising productivity of small scale food producers through access to land, other natural resources, financial services, markets and opportunities for value addition. This target is synergetic with poverty reduction (SDG 1.4), food security and malnutrition indicators (SDGs 2.1 & 2.2). Rising productivity and efficiency mean more efficient production of livestock products per unit of land or input. But climatic and structural issues, or steep overall increases in total demand could all hamper sustainable intensification, with environmental implications for irrigation water use, land degradation and greenhouse gas (GHG) emissions (trade-off C). Similarly, improved nutrition outcomes based on animal source food may be associated with overexploitation of feeding resources (trade-off D).

Between economic growth (SDGs 8 & 9) on the one hand and water availability (6), life on land (15) and climate action (13) on the other. There is a nexus of interactions between overall agricultural growth and productivity, and ecological and climate goals. In particular the extent to which growth is achieved through greater or more efficient use of pasture resources, or relies increasingly on supplementary fodder, chemical inputs and high performing breeds has implications for land use efficiency, GHG emissions, land degradation and water scarcity (trade-off E).

We structured the report along the following eight core topics, within which we review the relevant literature, link it to the SDG trade-offs introduced above, and identify the major emerging insights as well as open research questions. These topics and associated SDG trade-offs form the structure of the course Sustainable Development Goals and the Livestock Sector in Central Asia (Robinson and Petrick 2021), for which this report is the guiding text and sources reviewed here form the basis of the reading list.

Topic 1. Farm restructuring and land reform

Post-Soviet reforms have determined rural dwellers' access to land, livestock and other assets, which underlie rural living standards and inequality. They also determined currently observed farm size distributions, with implications for farm performance and productivity.

Restructuring resulted in three types of farm structure: (i) large enterprises, often successor institutions of state farms; (ii) individual farms, created from land distribution during restructuring; and (iii) rural households - holding kitchen gardens and small numbers of livestock. Households have the poorest land access and yet collectively own the majority of national livestock inventories.

Both livestock numbers and total production of meat and dairy produce have grown strongly in recent years, again with volumes largest in households. But there is variability between republics. In Kyrgyzstan, livestock and land inequalities are much lower than in other republics and in Kazakhstan individual farms also account for an increasing proportion of production. By contrast, in Uzbekistan, disparities are extreme but households often enter into contractual relationships with farmers to access land and inputs. Individual animal performance in the region is low compared to other emerging economies and tends to increase with farm scale. But crop yields and farm efficiency tend to decrease with size. Land access is positively associated with income and health in some parts of the region, but is less important where rural employment is available.

Research gaps in this area concern trade-offs between commercialisation of farming, and food security and poverty reduction. Approaches could include an examination of impacts of holding size distribution on SDG goals, for example, comparing highly skewed Uzbekistan with more equal Kyrgyzstan. An analysis of the technical efficiency of different scales and types of livestock farm would help assess the impact of farm restructuring on overall agricultural productivity. Such studies would support an improved understanding of the impacts of current agricultural support policies, which may favour certain types of structure over others, on SDG trade-offs.

Topic 2. Extensive livestock production: sustainable grazing systems

The vast majority of Central Asia's land area is covered by rangelands. Aridity makes livestock production the only viable land use on much of this land and extensive grazing can be a cost-effective alternative to fodder production in scarce irrigated areas. But whilst moderate grazing is compatible with many SDG goals, heavy or sedentary stocking can have negative effects on vegetation, soils and biodiversity. Extensive livestock production on arid rangeland is a major source of GHGs caused by enteric fermentation of poor quality roughage.

Central Asian livestock production systems traditionally relied on mobility to take advantage of spatial and temporal variation in vegetation productivity, optimizing animal weight gain over the year. With the loss of collective farms, herd ownership became fragmented, resulting in a partial breakdown of mobile systems. An increasing number of livestock owners are again travelling to remote pastures, but this re-expansion is dependent on the ability to cover costs of movement. Smaller owners remain on overgrazed village pasture, and are more dependent on fodder purchases, although collective herding systems may facilitate use of remote pastures. Following these grazing patterns, degradation is most severe around villages, whilst large areas of desert range are abandoned. The regional literature on sustainable pasture management focusses largely on property rights systems; most Central Asian countries have favoured individualised tenure, whilst Kyrgyzstan has introduced a common property regime. The impacts and economic viability of improvement of pasture productivity through technical measures is poorly understood.

Here, a major research gap concerns environmental, social and economic trade-offs associated with different pasture management systems, in particular between common property regimes and individualised forms of tenure. A related question is the extent to which increasing commercialisation will lead to a drop in mobility associated with intensification or increased use of remote pasture, again with SDG implications.

Topic 3. Intensification: fodder production and irrigation

Intensification of livestock production is often defined as an increase in livestock product units per unit of land through provision of higher quality forage or feed. It results in higher feed and land use efficiency, reducing GHG emission intensity. But opportunity and food security costs may be incurred where arable land is used for feed. Intensive systems may be less efficient than grassland-based systems in terms of nitrogen and water use, and can cause direct pollution from manure storage.

Across Central Asia, de-intensification occurred during the 1990s as competition with food and cash crops reduced the area planted to fodder crops, although recent increases are evident in some republics. Farmers near markets and specialising in dairy are most likely to invest in improved fodder provision, whilst those in remoter areas, specialising in meat production, provide less and lower quality fodder, often relying on winter pastures instead. Intensification often depends on irrigation which suffers from poor infrastructure and management, causing severe soil salinization. Improvement of water management institutions may have synergetic outcomes for multiple SDGs around water scarcity, inequality, food security, poverty and land degradation.

Bio-economic trade-offs of intensification strategies associated with commercialisation of beef and milk production have not been studied in the region whilst possible links between intensification, prices of livestock products and human diets and health are also poorly understood. Under-researched questions on irrigation include the extent and determinants of water supply inequality and potential trade-offs involved in improving irrigation water supply to smallholders.

Topic 4. Livestock species, genetic improvement and animal health

Improved animal breeds have made an important contribution to the growing efficiency of global livestock systems. But there can be trade-offs at the farm level through costs of the husbandry practices required to obtain full yield benefits and the environmental impacts of these practises. There are broader external costs in loss of genetic diversity if hardy breeds adapted to local conditions are neglected.

Much of the livestock genetic diversity existing during the Soviet era has been lost or diluted due to uncontrolled interbreeding after independence, whilst new market signals have led to changes in breed preferences. Some republics have imported highly performing animals from the West or Russia, but there may be a loss of focus on preservation of local breeds, many of which currently perform under potential. Disease poses a significant risk to livestock sector development in some republics, hampering export prospects and threatening human health.

Research gaps include assessment of the proposition that it is economically more rational to close the gap between actual and potential performance of local breeds than to promote higher performing ones, examining trade-offs between costs, farm and animal productivity and loss of genetic diversity. Improving animal performance may also have environmental impacts, as the ability of animals to use natural pastures and their feed requirements may incur farming system changes.

Topic 5. Value chain development

Increases in global demand for livestock products represent an opportunity for smallholders to increase their incomes. But increasing commercialisation may render these producers uncompetitive. In Central Asia, the majority of producers sell through ‘informal’ channels such as to traders and bazaars; most products sold are home-processed and unpackaged. Supply of sufficient volumes of livestock products meeting quality standards is inadequate, necessitating import both of finished packaged goods and raw ingredients for processing. In much of the developing world, establishment of contracts between processors and farmers including credit and extension has supported farmer integration into value chains. But in Central Asia, these arrangements appear to be unusual. Service cooperatives could also potentially link farmers to firms, but these institutions are weak in the region. Poor integration of the livestock sector with global value chains has been associated with lack of FDI and poor animal health and food safety systems. Only Kazakhstan has real potential to export large volumes of livestock products in the near future, although Kyrgyzstan is also making progress.

Research gaps include the relative importance and potential of cooperatives, private intermediaries and processors in facilitating vertical coordination, particularly in dairy value chains. The actual prevalence of contract farming, benefits for suppliers and determinants of participation is a second research area, with the role of informal arrangements particularly under-researched. Different policy and investment environments may promote vertical coordination or vertical integration of beef value chains; an analysis of the social and economic costs and benefits of each model would help inform government policies in this area.

Topic 6. Human diet and health

Undernutrition and food insecurity are still significant, particularly in Tajikistan. As incomes rise, these deficiencies are accompanied by rising overnutrition and non-communicable diseases (NCD) such as cardiovascular conditions. But the role played by livestock products in these patterns is poorly understood. Demand for livestock products is rising fast across the developing world. Typically at low incomes, improved access to these products is associated with positive health outcomes and at higher wealth, with negative outcomes. But empirical studies demonstrating these relationships are missing in Central Asia. The rising burden of NCDs in the region is also due to non-dietary factors, salt intake and trans-fats from poor quality vegetable oils, so the relative significance of increasing meat and dairy intake on disease burden is poorly understood.

Research could explore the health implications of different meat and dairy products in rural and urban diets compared to other causes of NCDs, and examine the links between livestock sector development, prices of livestock products and health outcomes.

Topic 7. Livestock production and climate change

Livestock production accounts for 15% of global GHG emissions. The bulk of this is methane from enteric fermentation, which accounts for over 50% of Central Asia's total agricultural emissions. Emissions are greatest in pasture-based systems due to poor digestibility of forage. Carbon sequestration on rangelands through improved grazing management is a poor mitigation solution as significant gains are likely only on severely degraded lands, will cease once soils reach carbon equilibrium, and are difficult to measure. Better husbandry and feeding may be a more practical way of supporting climate action goals, as well as those linked to improved productivity and commercialisation. Land conversion between arable and pastureland is a powerful driver of carbon sequestration and loss in the region.

Research gaps concern comparative studies of emissions associated with livestock production systems using different feeding and husbandry strategies. Of particular interest is whether increased vertical coordination in beef value chains may create synergies between emissions reduction, technical efficiency, animal productivity, reduced degradation and improved smallholder incomes. Abandoned croplands in Kazakhstan will continue to sequester carbon for many years to come, but less is known about the scale, drivers and trade-offs associated with pastureland conversion to cropland in other regions. In the field of adaptation, little is known about strategies already existing amongst livestock producers to cope with climatic variability, or synergies between these and other SDGs.

Topic 8. Services and policies for agriculture

Distortions to agricultural incentives and the allocation of spending to private or public goods can influence agricultural incomes and consumer prices. Governments in most Central Asian states support the agricultural sector through subsidised credit interest rates. Direct subsidies for livestock-related inputs and investments are low outside Kazakhstan but producers are partially protected through tariff barriers and import excise in several republics. Consumer prices and processing industries of certain commodities are protected through export bans. There is a trend towards trade liberalisation, but considerable non-tariff barriers remain, which also contribute to protection of livestock producers. All republics under-invest in agriculture compared to its economic importance. There is a lack of national policy frameworks for the development of agricultural extension services and weak links between international knowledge generation, national research institutes, and farmers.

At the national level, outside Kazakhstan there has been little analysis of the aggregate impact of producer and consumer support to the livestock sector. At the farm level, knowledge gaps concern the effectiveness of credit and subsidy programmes on farm growth and productivity across farm scales. There is almost nothing written on the extension needs of livestock producers, their access to knowledge, or outcomes of extension programmes. An assessment of extension models using SDG metrics could be one research approach, looking also at the extent to which knowledge is transferred to farmers from processors, suppliers and other farmers.

Trade-offs among sustainability goals in the Central Asian livestock sector: overview and approach of this report

The Sustainable Development Goals

On 25 September 2015, the 193 Member States of the United Nations adopted the 2030 Agenda for Sustainable Development, underpinned by 17 Sustainable Development Goals (SDGs) with 169 targets and 232 indicators (General Assembly of the United Nations 2017). The SDGs guide the actions of governments, international agencies, civil society and other institutions to achieve global sustainable development by 2030. In this report, we take them as an analytical framework for the analysis of sustainability trade-offs in the livestock sector of Central Asia, one of the partner regions of the SDG^{nexus} Network.

Figure 1. The sustainable development goals

Source: United Nations (2020)

The SDG^{nexus} Network

Supported by the German Academic Exchange Service (DAAD) from funds of the German Federal Ministry for Economic Cooperation (BMZ), the Centre for International Development and Environmental Research (ZEU), Justus-Liebig University, Giessen, Germany, established the SDG^{nexus} Network as a platform supporting research, networking and capacity building on the Sustainable Development Goals for the next generation of scientists. The Network aims to strengthen cooperation between academic partners from Latin America and Central Asia as well as from Germany. Research work in the network covers five research areas: (1) food systems, (2) water, (3) urban & rural areas, (4) natural resources and (5) SDG monitoring. Under the first of these areas, the present report focuses on the SDG nexus in livestock systems in the Central Asian republics of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, the four states in which SDG^nexus Network partners have a presence.[1] The fifth republic, Turkmenistan, is covered in less detail, with information limited to comparative tables and figures.

Identifying synergies and trade-offs among SDGs: the nexus approach

The network takes a nexus approach because each SDG can neither be understood nor reached in isolation. Many pairs or groups of SDGs exhibit synergies, whereby progress in one is associated with progress in others. Inversely, progress in some SDGs are associated with trade-offs in others. Pradhan et al. (2017) documented these associations empirically by using SDG progress reports to measure the strength of correlations between pairs of goals. They found frequent trade-offs between SDGs 8 (*Decent work and economic growth*); 9 (*Industry, innovation, and infrastructure*) 12 (*Responsible consumption and production*); and 15 (*Life on land*). These emerge from the difficulties in reconciling economic growth with environmental sustainability. On the other hand, they found that synergies were more common, outweighing trade-offs for most SDGs and countries. For attaining SDGs, synergies can be leveraged but the trade-offs need to be overcome by deeper changes in current strategies (Pradhan et al. 2017).

The idea of synergies and trade-offs between pairs of SDGs can be taken further using a nexus approach, which looks at more complex interlinkages in a structured way, in particular between the governance of resources and development objectives. Resource governance has traditionally been addressed by looking at problems as single dimensions – for example finite fossil energy stocks are addressed through development of alternative energy sources; land constraints by food production technologies; water shortages by efficiency technology (Giampietro 2018). However, each solution may involve knock-on effects in other areas or could have benefitted from unrealised synergies. If such interlinkages are ignored, SDG implementation may lead to further acceleration of natural resource degradation, with consequences for human societies and for the probability of meeting the SDGs (Bleischwitz et al. 2017).

The nexus concept *"emphasizes the examination of critical interlinkages across resources, particularly synergies and trade-offs, in a more integrated manner rather than looking at resource governance of individual areas such as water, alone"* (Bleischwitz et al. 2018). But what would a nexus approach look like in research terms?

Firstly, questions should be framed in a cross cutting manner to include multiple resource management and human development objectives such as those encapsulated in the SDGs. Bleischwitz et al. (2017) suggest a research approach based on concepts such as resource efficiency and the circular economy, which describe stocks and flows of materials and energy through society. Life-cycle approaches, input-output analysis and system dynamics approaches would all allow hypothesis testing and estimation of trade-offs and synergies (Bleischwitz et al. 2017).

A conceptually simpler and more practical approach is trade-off analysis between sets of indicators, which is a fast growing field in research on sustainable intensification and climate-smart agriculture. An understanding of the interactions between desired outcomes from agricultural systems (e.g. crop yields, biodiversity, human nutrition) can help policymakers to optimize agronomic, environmental and socioeconomic outcomes (Kanter et al. 2016, Klapwijk et al. 2014).

[1] For a full list of partner organisations, visit www.sdgnexus.net.

Livestock production systems establish a particularly strong case for trade-off analysis. The sector occupies around 30% of the Earth's surface (Steinfeld et al. 2006) and is often associated with land degradation, land conversion, high GHG emissions, diminished water quality, low land use efficiency and epizootics. But it also contributes to global food security - utilising land unsuitable for arable crop production; converting low-quality roughage to protein for human consumption, and facilitating nutrient cycling. Livestock are a source of nutrition, wealth and income but also contribute fertilizer and traction, and provide insurance and savings in markets where credit and banking needs are poorly served (Herrero et al. 2009, Salmon et al. 2020).

Trade-off approaches aim to identify and measure interactions between benefits and harm associated with food production, comparing the influence of different systems, decisions and policies (Salmon et al. 2018, Takahashi et al. 2018) For Kanter et al. (2016), indicators are the fundamental units of agricultural trade-off analysis. Some SDG indicators can be used directly as metrics to measure progress towards the goal in question (for example GDP increase, official flows to agricultural sector). Others, such as the sub-indicators *2.4.1 Proportion of agricultural area under productive and sustainable agriculture* and *15.3.1 Proportion of land that is degraded over total land area* (General Assembly of the United Nations 2017) require separate metrics (such as crop yield per unit of input or soil carbon content). Standard metrics for comparative analyses have been developed for studying economic-environmental trade-offs or sustainable intensification (Smith et al. 2016) and can also be adapted to SDG trade-off analysis (Kanter et al. 2016).

Once data on metrics of interest are available, trade-off curves can be constructed by plotting values of measured indicators against each other. The shape of the trade-off curve reflects the degree of complementarity between these objectives based on empirical data (Tittonell 2013). But such empirical approaches (outside controlled experiments) may not identify the mechanisms linking cause and effect. Bio-economic simulation and optimization modelling attempt to predict relationships between goals, identifying 'ideal' outcomes which maximise synergies or minimise trade-offs (Klapwijk et al. 2014). Kanter et al. (2016) review such bio-economic models, which look for optimal arrangements of multiple objectives (for example maximizing profit and organic matter balance; minimizing labour balance and soil nitrogen losses). Model development can be costly if relationships need to be characterised from scratch, but in the livestock sector a number of farm models including environmental, economic and social dimensions have been developed for European systems (Linden et al. 2020). Klapwijk et al. (2014) cautions that such models are best used in combination with participatory approaches, in order to understand the objectives for which livestock are kept, beyond purely economic indicators based on inputs and outputs (Salmon et al. 2018).

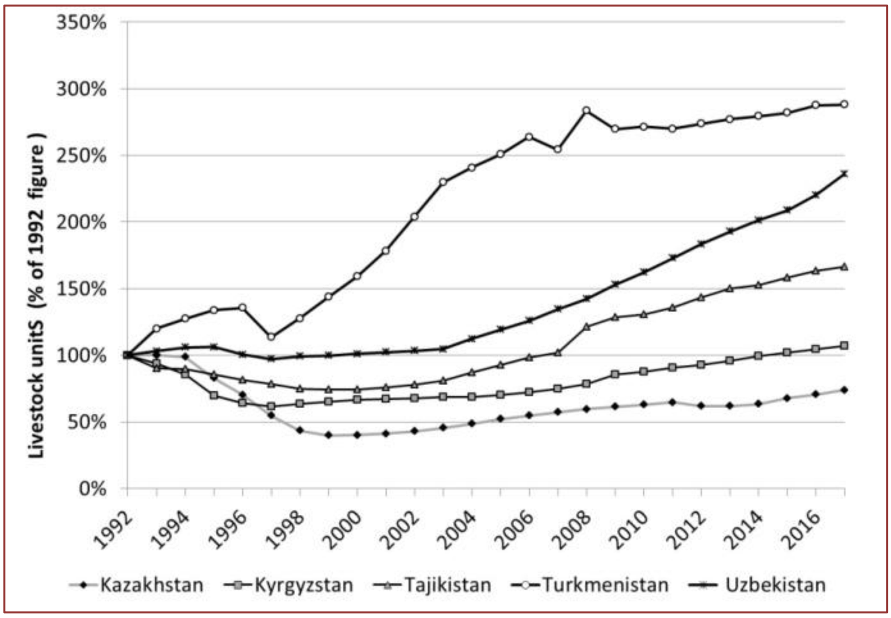
As the above discussion suggests, much of the literature on trade-offs in food systems focusses on the areas of economy-environment interactions, opposing metrics of agricultural productivity or economic growth, with environmental indicators. But trade-offs are also strongly influenced by the presence or absence of markets and public policy in services, subsidies and prices (Kanter et al. 2016). Most sustainable intensification type analyses do not consider market access or indicators of human wellbeing and equality such as nutrition or resource access (Smith et al. 2016).

If commercialisation of agriculture is achieved to the detriment of small farmers, then there may also be trade-offs between food security, poverty reduction and certain indicators of economic growth, areas in which global SDG trade-offs have also been found to be high (Pradhan et al. 2017). For some, livestock production is a subsistence activity, important for nutrition and as a form of insurance. For others, it is a commercial activity and source of cash income, whilst policy makers may wish to see the sector contribute to economic growth and as a source of foreign exchange. Producers may be confronted with the decision to commercialise and specialise, whilst governments are faced with choices to support larger commercial farms or smallholders in multiple policy areas such as land reform, subsidies, infrastructure, attraction of FDI, credit, agricultural extension, water supply and the legislative environment for contracting and cooperative development. In these policy areas, commercialisation of agriculture may not always be compatible with increasing smallholder incomes or reducing inequality. For example, large and intermediate suppliers may best serve the development of processing enterprises and their integration into value chains, whilst SDG targets for poverty and hunger reduction specifically concern small producers.

Livestock in Central Asia

Once a supplier of meat, dairy products and animal fibre to the Soviet Union, the Central Asian livestock sector suffered severe reversals following independence. Economic collapse combined with the breakdown of feed supply chains, long distance grazing management and veterinary systems led to plummeting productivity and, in some republics, loss of a large proportion of the national herd (Figure 2, Robinson et al. (2012), Suleimenov et al. (2006)). With the disappearance of inter-republic trading links within the Soviet Union, marketing became a domestic and even local affair (Kerven 2003, Suleimenov et al. 2006).

Figure 2. Livestock numbers in Central Asia 1992-2017
(in livestock units, as % of 1992 figure)*



Source: Reproduced from Robinson (2020); source: FAOSTAT.
*LU: based on Eurostat (2020), counting all cattle at a value of 1 LU, sheep and goats as 0.1, and horses as 0.8. Camels are not included in the Eurostat scheme and have been assigned a value of 1.

Despite this recent downturn, international observers and donor agencies cite the livestock sector in Central Asia as an area with tremendous growth potential (Buruncíuc 2019, OECD 2011). Outside oil-rich Kazakhstan, agriculture still accounts for between 10% and 20% of GDP, with livestock contributing from 30% to over 50% of total agricultural production value (Robinson 2020). Increasing urban incomes have stimulated domestic demand for livestock products whilst, given their extensive rangelands, Kazakhstan and Kyrgyzstan are widely expected to become exporters of meat and dairy products once again. Rapprochement of Uzbekistan and its neighbours initiated by the new President of Uzbekistan Shavkat Mirziyoyev as well as the emergence of new transport and trade infrastructure under China's Belt and Road Initiative has spread optimism concerning new economic opportunities (Pomfret 2019). It has been estimated that there are around ten million poor livestock keepers in Central Asia today (Robinson et al. 2011), and these opportunities may also represent improved prospects for rural smallholders.

However, since 1991, Central Asian countries have struggled to identify suitable development strategies for their livestock sectors. Livestock numbers are growing fast (Figure 2) but availability of feed and fodder, the import and subsidisation of which underpinned the sector during the Soviet period, appears to severely limit sector growth today. The contribution of the region's vast semi-arid pastures to animal nutrition is thought to be hampered by a range of institutional and infrastructural issues, and growth is undermined by lack of effective processing and marketing, and weak enforcement of phytosanitary standards (Buruncíuc 2019, Pomfret 2008a).

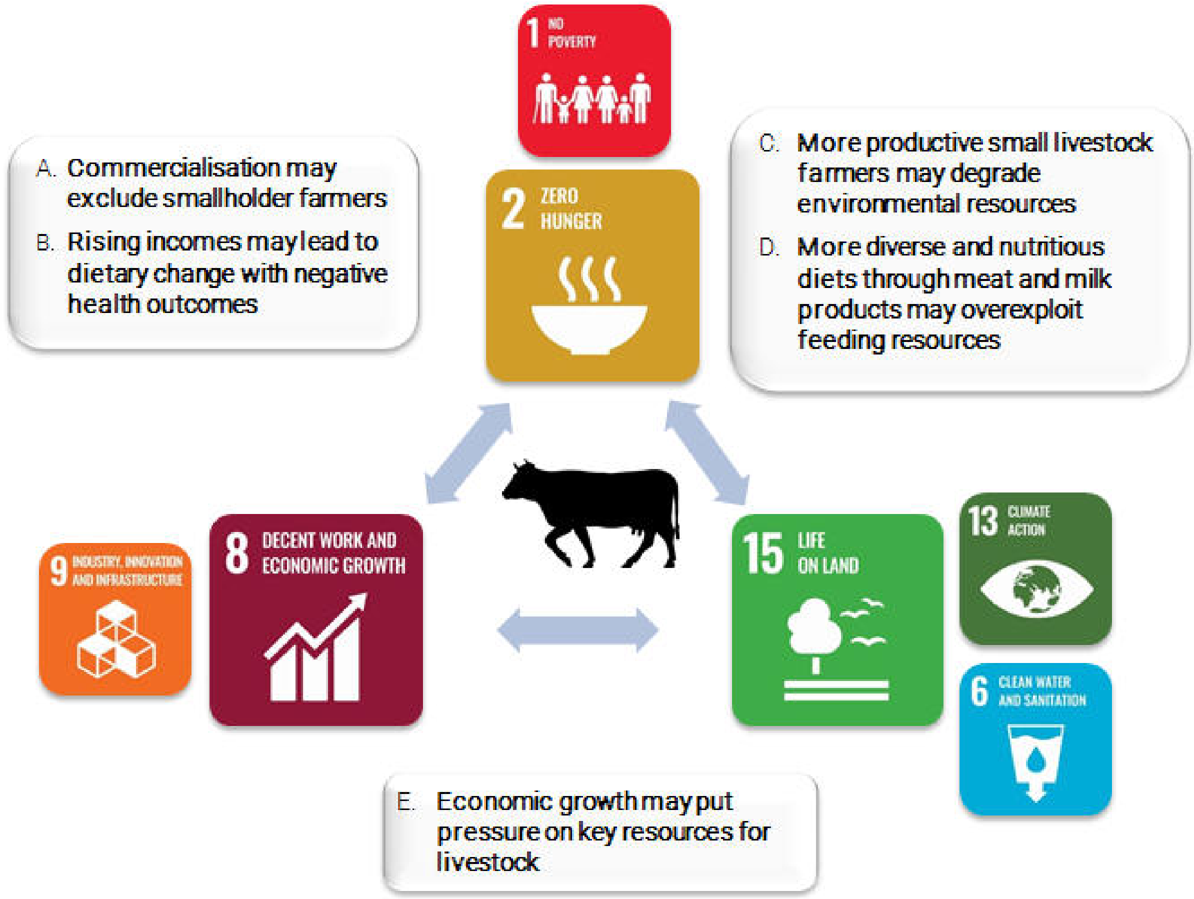
Goals and approach of this report

In Central Asia today, livestock are kept for a wide range of purposes, ranging from subsistence and savings, through small-scale income generation, to large commercial operations. Owners have a multitude of different strategies for grazing, feeding and fattening their animals and for accessing markets. During the past 25 years, a literature emerged that documents many of these purposes and strategies in detail, often in the form of empirical case studies. However, few systematic reviews synthesising current knowledge on the Central Asian livestock sector exist. None use the SDGs as an analytical framework.

The goals and needs of different livestock producers naturally align with quite different SDGs, so policies supporting one type of producer may create trade-offs for others. The present report thus aims to take stock of the existing knowledge on Central Asian animal husbandry in the light of SDG trade-offs. It extracts the major insights from the literature to date, arranges and summarises them along a set of key research and policy areas, and identifies the remaining gaps in our understanding of the sustainability trade-offs in Central Asian livestock. In this way, we hope to define a research and training agenda for the SDG^{nexus} Network.

Following the above outline of the SDG nexus approach and the authors' prior understanding of the livestock sector in Central Asia, we identified a distinct set of trade-offs relevant to this sector. We group these trade-offs along three dimensions (Figure 3). We hypothesise that the SDGs 2, 8 and 15 constitute the major nexus relevant for livestock development in Central Asia: the simultaneous establishment of sustainable, livestock-based food systems represented by SDG 2 ("zero hunger"), the growth of economic opportunities and income represented by SDG 8 ("decent work and economic growth"), and the responsible use of natural resources relevant for animal husbandry represented by SDG 15 ("life on land"). Subordinate SDGs that we also consider relevant for the livestock nexus in Central Asia include SDG 1 (no poverty), SDG 6 (clean water and sanitation), SDG 9 (industry, innovation and infrastructure), and SDG 13 (climate action).

Figure 3. The livestock nexus in Central Asia: relevant SDGs and their trade-offs



Note: The official SDG targets listed in Figure 3 and Table 1, with associated indicators are given in the Annex.

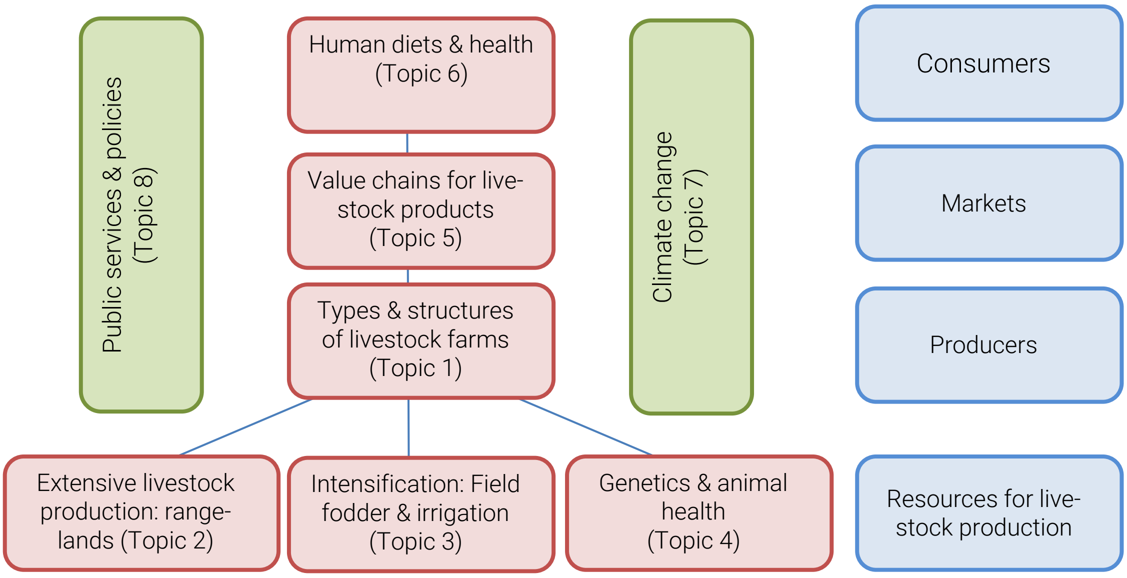
Source: authors.

Topics covered in this report

In this report, we discuss these three major trade-off dimensions in the framework of eight Topics (chapters), which follow the major stages of livestock value chains, together with two cross-cutting topics: public services and policies, and climate change (Figure 4). The contents of the eight Topics are summarised below. Each begins with a discussion of relevant SDG targets and trade-offs and ends with a summary of major insights and research gaps. In the final chapter of the report, we return to the major trade-offs outlined here and summarise the research agenda from our review of current wisdom.

These topics and associated SDG trade-offs form the structure of the course Sustainable Development Goals and the Livestock Sector in Central Asia (Robinson and Petrick 2021), for which this report is the guiding text and sources reviewed here form the basis of the reading list.

Figure 4. Dimensions of livestock systems in Central Asia addressed in this report



Source: authors.

Topic 1 on the livestock producers themselves focusses on land and structural reforms since the 1990s. These have resulted in a range of producer categories, having very different access to land and livestock holdings. We look at the implications of these reforms on inequality, poverty, farm efficiency and animal productivity and examine the associated SDG synergies and trade-offs concerning the different farming structures identified. Notably, an understanding of these different categories of livestock producer is important for subsequent discussions as synergies and trade-offs discussed in other topics may differ for each group.

Topics 2 to 4 on the factors of production examine the three determinants of livestock production: pastures, fodder & irrigation and animal genetics & health. We look here at questions of sustainable intensification, including trade-offs between expanding pasture use through increased livestock mobility, and intensification through greater feed production and use of high performing breeds. The design of institutions for pasture and water management, their impacts on equality of resource access and sustainability of use are also discussed.

Topic 5 on value chains covers many of the mechanisms of improving smallholders' participation in markets, which are highly synergistic with a large number of SDG goals, and asks to what extent this is occurring in Central Asia. Lastly, moving to the top of the value chain, Topic 6 focuses on the nutrition transition and food consumption patterns, comparing extent and drivers of under and over nutrition between republics and wealth groups.

Two cross-cutting topics affect all dimensions of livestock production systems. Topic 7 on climate action investigates the evidence that GHG emissions can be reduced through improved pasture management and livestock husbandry, and discusses synergies of adaptation measures with other SDG goals. Topic 8 goes on to examine government policies and service provision including credit, subsidies, trade and agricultural extension, looking particularly at whether these policies support some farm structures over others, and at implications for SDGs.

Major trade-offs

The major trade-offs within the livestock nexus defined in this report are the following:

(A) Agricultural commercialisation may exclude smallholder farmers

In one way or the other, all Central Asian governments promote the commercialisation and extension of agricultural value chains, to better serve urban consumers and promote economic diversification and the generation of export revenue. A key concern is how the many smallholder farmers in Central Asia might benefit from enhanced value chains. So far, fragmentation of livestock production hampers market development, with a large proportion of animals owned by small producers. Value chains are often short, ending at local markets, and few mechanisms link all but the largest producers directly to finishing operations, retail outlets, processors or even abattoirs. The need to supply large product volumes for processing industries and for export is a factor affecting investment decisions in different types of production systems, both by farmers and governments. There are trade-offs between supporting larger farming units or vertically integrated farms, more likely to provide quality and quantity of product, and finding ways to boost productivity of smaller farms and to integrate them into value chains, with advantages for poverty reduction, rural employment and food security. The implications for SDGs of farm restructuring and land reform, which resulted in the producer landscape we see today, are covered in Topic 1, while value chain development is discussed in Topic 5. The trade-offs resulting from policies on subsidies, finance, extension services and trade policy are covered under Topic 8.

(B) Rising incomes may lead to dietary change with negative health outcomes

Although food insecurity and nutrient deficiencies continue to exist in Central Asia, the region is also a hotspot for cardiovascular disease. As observed across much of the developing world, increasing incomes may aggravate this problem, as these are often associated with a 'nutrition transition' towards increased consumption of meat and processed foods, contributing to obesity, cardiovascular and other non-communicable diseases. Conversely, where undernutrition is prevalent, livestock may make a strong positive contribution to health outcomes. SDG target 2.2, including indicators of over and undernutrition, is relevant here.

(C) More productive small livestock farmers may degrade environmental resources

The intensification of livestock operations through modernised value chains, access to deeper and higher priced markets along with higher capital input and stocking densities may increase pressure on natural resources, leading to overgrazing, water scarcity, inappropriate manure disposal and rising GHG emissions. Concurrent expansion of pasture use and intensification of production are both likely, but these two pathways to growth are implicated in different sets of environmental trade-offs. Extensive systems suffer from low feed conversion efficiency, producing high greenhouse gas emissions per unit of product (Topic 7). This issue can be mitigated by optimising pasture management; improving winter feed digestibility and hastening attainment of sales weight by fattening. But such strategies demand either expensive feed imports or higher use of scarce irrigable land for feed production. On the other hand, attempts to protect natural resources may result in exclusion of the poorest, so improved institutional solutions for management will be important to the resolution of these trade-offs. There are also trade-offs between low feed conversion efficiency of extensive systems and the low land-use efficiency of intensive systems, with their potentially high opportunity costs. Irrigated lands (discussed in Topic 3) are themselves subject to very high environmental pressures, with poor management leading to severe salinization and water scarcity. Intensification on these lands, if based on short-term, high-input approaches, will cause further environmental degradation, which will inevitably feed back negatively on production aims. The environmental impacts associated with different pathways towards development of livestock production on pastures, water management and climate change are discussed under Topics 2, 3 and 7.

(D) More diverse and nutritious diets through meat and milk products may overexploit feeding resources

More diverse and nutritious human diets, including high proportions of meat and milk products, may lead to growing animal stocks and increased demand for fodder resources, including pastures, irrigated arable land areas for fodder production, and water resources. Improved human nutrition would thus be achieved at the cost of more thinly stretched land and water resources used for rearing animals. The relationships between food security, pasture and water management and climate change are discussed under Topics 2, 3 and 7.

(E) Economic growth puts pressure on key resources for livestock

Recent economic growth in Central Asia came along with many side effects also observed in other emerging economies: urbanisation, rising demand for individual housing and transport, and overnutrition from growing incomes. While the latter is the subject of trade-off B, many other features of economic growth directly influence natural resources that are key to livestock production. For example, pastures may be turned into industrial or residential areas; new transport corridors may fragment grazing lands and interrupt migration routes of herders. Emerging industrial sites pollute water resources and growing use of fossil energy sources and other emissions leave a larger carbon footprint. All of these place further constraints on the sustainable use of land and other natural resources for livestock husbandry.

Growing urban demand for livestock products and sector expansion for import substitution and export are likely to result in continued growth in livestock numbers but also to changes in production systems. However, if growth is achieved through new water-efficient technologies, then synergies between SDGs 8 and 15 may be created. Land use for grazing at moderate stocking rates has synergies with biodiversity goals, whilst intensification of feed production on croplands can free land for the conservation of species that require grazing lands to survive. But heavy grazing and expansion of cropland for feed will incur environmental trade-offs (Topics 2, 3 & 7).

Table 1 summarises how each Topic shown in Figure 4 relates to the main trade-offs listed in Figure 3. It thus provides a list of more specific trade-offs and indicates their relevance for each element in the value chain.

Table 1. Relationships between major trade-offs and topics covered in the report

Trade-offs	Topic 1 Reform & restructuring	Topic 2 Extensive production	Topic 3 Intensification	Topic 4 Genetics & health	Topic 5 Value chains (VC)	Topic 6 Diet & health	Topic 7 Climate change	Topic 8 Services & policies
Trade-off A. Commercialisation excludes smallholders.	Reforms favour large farms, reinforcing inequalities.	Commercial farmers have better access to grazing than smallholders.	Water reforms favour larger farmers. Feed production means less land for food.	High yielding breeds promoted to detriment of local varieties.	Smallholders unable to access new value chains.			Public policy favours large farms.
Trade-off B. Income growth induces malnutrition.					Globalisation of value chains increases import of processed foods.	Rising consumption of meat & dairy has negative health outcomes.		
Trade-off C. More productive small livestock producers degrade environmental resources.	Farm restructuring occurs to detriment of NRM* systems.	Increased livestock production puts pressure on pasture.	Greater access to irrigation water causes scarcity.	Expansion of livestock increases disease transmission with wildlife.	VC development incurs environmental costs (inputs, infrastructure, transport).		Expansion of livestock sector increases carbon footprint.	
Trade-off D. Better nutrition overexploits resources.		Increased consumption of livestock products puts pressure on pastures.	Increasing feed production puts pressure on water and land.			Improved nutritional outcomes come at the cost of resource degradation.	Rising consumption of livestock products raises GHG emissions.	Public policies to support food security have environmental trade-offs.
Trade-off E. Economic growth compromises production resources in agriculture.	Growing economic activity occurs to detriment of NRM* systems.		Intensification leads to water pollution, salinization, water scarcity.	Livestock expansion causes disease in wildlife. Improved breeds have greater feed demands.	VC development incurs environmental costs (inputs, infrastructure, transport).		Industrial growth increases carbon footprint.	Industrial policies supporting sector growth have environmental trade-offs.

* Natural Resource Management

Topic 1. Farm restructuring and land reform

Agricultural reform and the sustainable development goals

In this section, we look at the farming structures in which livestock are kept and at how these came about through the land reforms and restructuring of the past 30 years. These processes are important to the SDGs as they have determined access to land, livestock and other assets by the rural population, which in turn underlie rural living standards and inequality. They have also influenced productivity and farm efficiency, which are important for SDGs 2 and 8. In the first part of this topic, we describe the reform processes and their outcomes in terms of asset ownership and access; in the second, we describe the consequences for animal productivity, farm efficiency and rural living standards. Our focus here is on trade-off A (Figure 3), while trade-offs C and E are primarily dealt with in Topics 2, 3 and 7.

How land and livestock are distributed is particularly important for SDGs 1, 2 and 10. Livestock ownership in itself has positive impacts for SDGs 1 and 2 through diet (Topic 7) and income (Topic 6). Globally, not all studies find relationships between herd or flock size and household wealth but livestock are often more equally distributed across wealth groups than land (Otte et al. 2012). Animals are more likely to survive environmental shocks than crops as they can digest a wide variety of feedstuffs. They represent a stock of food and income, which can be mobilised at times of need, and smooth food and cash availability (Otte et al. 2012, Salmon et al. 2018). As agricultural risks increase, the insurance value of livestock increases and some studies have attempted to quantify these types of indirect benefit (Hänke and Barkmann 2017, Moll 2005).

Land access is also crucial to livestock development and for the potential of the sector to contribute to the achievement of SDGs 1 and 2. This is because the two major processes that can improve smallholder incomes are increases in productivity through intensification and greater integration into value chains, both of which are greatly facilitated by access to land. Intensification often depends on integration of crop and livestock production through mixed farming (Mcintire et al. 1992). If owned, land can be used as collateral for loans. Small land holdings are also said to be one barrier preventing smallholders achieving necessary increases in labour productivity needed to participate in value chains (FAO 2018a).

Farm structures and land reform post 1991

The development of farming structures is rooted in the reform processes followed by Central Asian republics since their common past in the collectivised agricultural system of the USSR. Immediate outcomes were evident from the collapse in livestock inventories of up to 75% in countries like Kazakhstan and Kyrgyzstan, which moved comparatively quickly to a market economy (Figure 2). Where restructuring was partial or slower, immediate collapse was avoided, but the slow pace of reform has had other negative consequences for development of the sector.

All five republics share three basic types of agricultural structure – households (HH), individual farms (IF) and large enterprises (E). In terms of land, households typically hold only kitchen gardens, although many in Uzbekistan, Tajikistan and Turkmenistan received additional parcels through presidential decrees. Enterprises often started out as privatised state farms. Subsequent breakdown of these into individual farms occurred at different speeds in each republic and usually involved distribution of land shares to former workers. In most republics, these beneficiaries of land reform generally accede to the legal status of registered 'farmer' (Lerman et al. 2004, Swinnen and Rozelle 2006).

In Kyrgyzstan, the process of share distribution was active, and all eligible farm workers received arable land shares that eventually became fully marketable private property (Akramov and Omuraliev 2009). In Kazakhstan and Tajikistan farmers were issued with paper shares to be converted to physical plots through expensive or opaque administrative procedures, resulting in only a partial transfer of land to those eligible (Hierman and Nekbakhtshoev 2018, Petrick et al. 2011, Robinson et al. 2008). In Uzbekistan, there was no wholesale distribution of land to workers; instead individuals desiring land had to apply to district authorities for leaseholds allocated by tender (also true of new land acquisitions in Kazakhstan). The resulting individual farms have been categorised into mixed farms and livestock farms (the latter of which must own 30 head of cattle equivalents with at least 0.33 ha of land per head). Households are limited by law to 0.35 hectares of irrigated land and cannot bid in land auctions (Naumov and Pugach 2019). It was estimated that by 2008 only 10% of rural households had managed to register as farmers and obtain land for lease (Zorya et al. 2019). Some householders work on this land as labourers, sharecroppers or tenant farmers (Djanibekov et al. 2013, Veldwisch and Spoor 2008).

In Kyrgyzstan, Tajikistan and Uzbekistan enterprises are successor organisations of collective farms and concern state or quasi-state livestock breeding operations accounting for a small proportion of the livestock sector (although in Uzbekistan they still control large areas of grazing land – see Figure 5). In Kazakhstan, large enterprises are run as private companies or agroholdings, owning a small proportion of national livestock inventories, but a much larger proportion of land and other assets (Petrick et al. 2013).

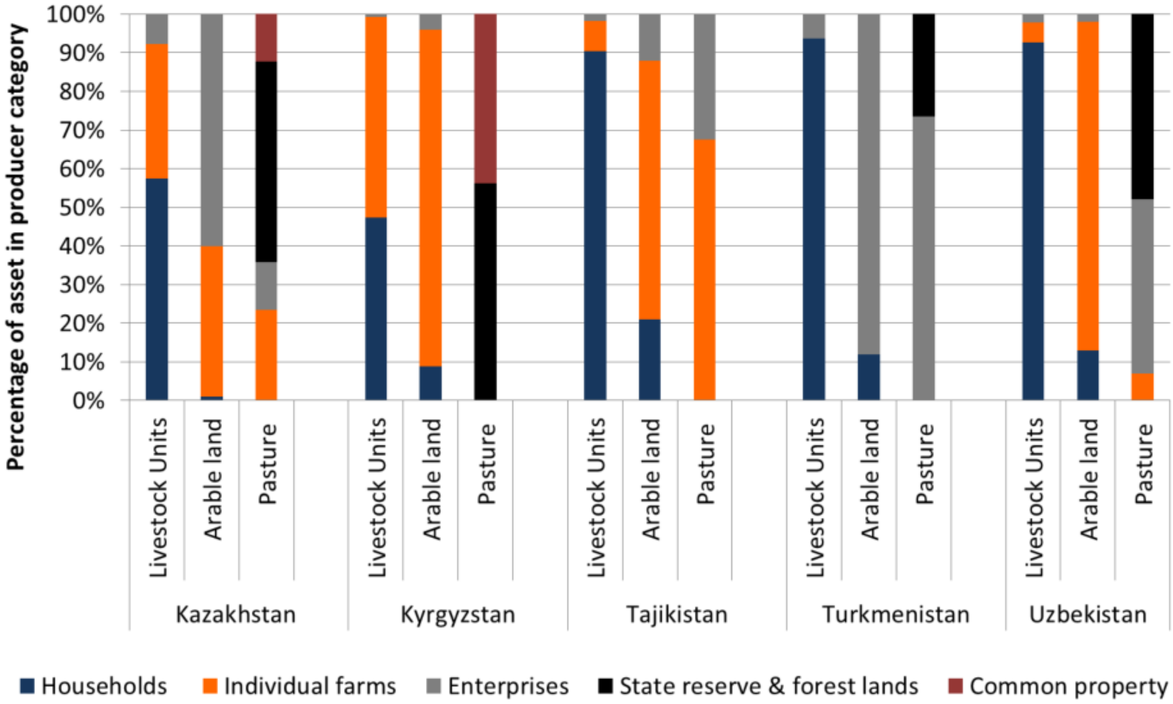
Reform was slowest in Turkmenistan, where state farms were simply renamed as farmers' associations, which are still subject to state plans. However, production was devolved to members, who could rent cropland or livestock herds - providing part of production to the association (Behnke et al. 2005, Lerman and Stanchin 2006). Specialised livestock breeding farms (holding the bulk of pastures), changed less, with tasks continuing to be performed by salaried workers (Robinson et al. 2018). Both types of farm are now undergoing restructuring. Legislation opening the possibility for land-owning individual farms was passed in 1993, but until recently government policies prevented the development of this sector (FAO Investment Centre 2012).

With the exception of Kyrgyzstan and Turkmenistan, the reforms described here initially applied to both arable and pastureland. Details on pasture reform, including subsequent developments affecting these lands alone, are described under Topic 2.

Livestock and land ownership distributions

The outcomes of reform in terms of formal asset ownership or access are evident from Figure 5, which compares the distribution of livestock and land between farm structures. In Kyrgyzstan, individual farms control 88% of arable land and 52% of livestock units. They account for 62% of agricultural output, compared to 36% for households and 2% state or collective enterprises (National Statistics Committee of the Kyrgyz Republic 2018). Both individual farms and households have access to common pastures managed at the municipal level. By contrast, in Uzbekistan, the proportion of cattle in individual farms and enterprises is small, and decreasing. Households hold 93% of livestock units, yet hold little arable land and have no formal access to pasture (Figure 5). Enterprises, with 1% of animals, control 45% of grazing lands. Tajikistan is similar in that households produce 95% of the monetary value of livestock production whilst most land is held in farms and enterprises. Turkmen farmers' associations and state livestock farms hold about 70% of pastures and 90% of irrigated land, yet over 90% of livestock units are privately owned.

Figure 5. Livestock and land access by farm structure



Adapted from Robinson (2020).
Sources & definitions livestock units: Livestock units calculated from raw livestock statistics using Eurostat (2020). Uzbekistan (2017): Djanibekov and Petrick (2020), updated, Kazakhstan & Kyrgyzstan (2017): national statistics (downloadable tables). Tajikistan (2018): Statistical Agency of the Republic of Tajikistan (2018c). Turkmenistan (2017) State Committee of Statistics of Turkmenistan (2018). Turkmen figures for households include both small-holders and larger farms leasing land or livestock from the state, but which lack specific legal status. Land and state livestock leased by these farms are classed under state enterprises, and private livestock with those of households in statistics. Individual farms with their own land and livestock exist, but are also aggregated with households in recent statistics.
Sources & definitions pasture area: In all republics, state reserve refers to unallocated state lands; forest land refers to pastures managed by the forestry department. Turkmenistan (2018): State Committee of Statistics of Turkmenistan (2018). Pasture in enterprises comprises 30% in farmers associations; 41% in state livestock farms (currently undergoing privatisation) and 1% in private enterprises such as joint stock companies. Uzbekistan (2017): Naumov and Pugach (2019) citing Narbaev (2018). Kazakhstan (2013): Kazakhstan Statistical Agency (2014). Households may use common pasture owned by rural municipalities, for which areas were obtained from the website of the Committee for Management of Land Resources. Kyrgyzstan (2014): Department for Cadastre and Registration of Immovable Property of the Kyrgyz Republic (2014). Tajikistan (2012): national statistics, provided by Zvi Lerman. Areas of municipal land and areas leased by pasture users associations (which may include households) exist but are unavailable in statistics.
Sources & definitions arable land area: Uzbekistan (2017): Djanibekov and Petrick (2020). Turkmenistan (2018): State Committee of Statistics of Turkmenistan (2018). Many 'households' lease arable land from state enterprises - so these have greater access to land than apparent from figures. Kazakhstan & Kyrgyzstan (2017): national statistics (downloadable tables). Tajikistan (2017): Statistical Agency of the Republic of Tajikistan (2018b).

In Kazakhstan, the proportion of livestock and land in individual farms is increasing. Nonetheless, households still hold around 60% of livestock yet have formal access only to common grazing around villages, shown in Figure 5 as common property (Petrick et al. 2014). As elsewhere, the major difference between households and registered farms is one of scale. For example, Kazakhstan's 1.6 million rural households have on average two cattle and seven sheep or goats; whilst the mean for its 200,000 family farms is 11 cattle and 34 small stock (Djanibekov and Petrick 2020). There is little specialisation, as different livestock species have different roles and also help to spread risk (Robinson et al. 2021). This is true across farm sizes, reflecting similar observations from other regions of the developing world (Otte et al. 2012). Across the region, livestock ownership exhibits a highly skewed (or log normal) distribution, with very large numbers of small owners and a few large owners, a pattern which exists also *within* each of the three farm type categories.

The patterns for pasture access shown in Figure 5 are somewhat misleading in that they represent legal access to land, whilst informal arrangements are not accounted for. We will see in Topic 2 that many livestock owners graze their animals on state lands; others sublease or send livestock to pastures with leaseholding relatives or shepherds for a fee (Kerven et al. 2016, Robinson et al. 2010b). Landless householders may access croplands through subleasing or sharecropping. In Kazakhstan and Uzbekistan, sharecropping has been associated with insecure land tenure arrangements, distorted (or absent) input markets, lack of liquidity and access to land for a second crop, which is often part of the arrangement (Mukhamedova and Pomfret 2019). Subleasing is common wherever land markets are inefficient and is also likely where farmers have scattered land holdings or lack capital and expertise to operate their farmland, whilst salaried employment is common for labour intensive crops such as cotton (Djanibekov et al. 2013).

It has been suggested that individual farms are the organisational form most likely to further agricultural development in the region (Lerman 2004, Lerman and Sedik 2017b, Spoor 2012). Thus, a question raised by the figures presented is why this sector is not more developed. The level of ease with which the fruits of restructuring were initially distributed to the population explains a large part of the variation in observed use and ownership patterns. Today, there are also significant barriers to entry and even policies which force people out of farming. Transaction costs of obtaining new land are high in most republics, favouring the wealthiest and best connected farmers. In Uzbekistan and Turkmenistan, farmers were obliged to sell cotton and wheat to the state, at prices well below those of the market (Pomfret 2008a). This is now changing in Uzbekistan, but even here new plans to diversify are state led, whilst forced consolidation (through land seizures from those farmers considered to be ineffective) has reduced the number of individual farms from around 220,00 in 2008 to just under 80,000 in 2014 (Naumov and Pugach 2019). The rational for this was that many farmers received multiple non-contiguous parcels, which hinders the functioning of irrigation and drainage systems, but none received compensation (Djanibekov et al. 2012). In Turkmenistan, individual farmers were initially given the poorest land and also became subject to expropriation, losing 80% of holdings between 1998 and 2012 (FAO Investment Centre 2012). This sector has only recently stated to expand again (Aganov et al. 2019).

In Kazakhstan and Uzbekistan, 'clusters' have been promoted by governments with the intention of promoting geographically proximate food production and processing industries. These have been criticised in Kazakhstan as an attempt by government to 'pick winners', likely to be less successful than market-led mechanisms based on discovery and competition (Wandel 2010). Evidence from cluster policy implementation in the Kazakh cotton sector suggests that increasing government interference has led to steep declines (Petrick et al. 2017a). In Uzbekistan, although cotton production targets have been abolished, crop placement systems still limit farmer choices and the cluster system tends to simply replace the government monopoly on cotton purchase with a private one. On the other hand, private investment has achieved technology adoption and yield increases whilst lack of competition may even favour development of a contract system with farmers (Zorya and Babaev 2020). Many of the studies reviewed in this section focussed on arable farming; scholars of agricultural development in Central Asia have paid less attention to the restructuring of livestock operations, although literature on pasture reform is significant and reviewed under Topic 2.

Restructuring and gender

Women in Central Asia tend to access land and livestock through their households and male relatives. Only 12% of individual land holders are female in Kyrgyzstan and 10% in Tajikistan (Rocca et al. 2014). Herding is almost exclusively a male domain, but processing of milk products, supplementary feeding, raising young animals and marketing dairy products are largely female tasks (Scalise and Undeland 2016).

However, in particular in countries with high labour migration, new roles have been emerging for women. In Tajikistan, there has been a feminisation of agriculture with up to 35% of individual farms operated by women[2], and increased participation in wage labour and water management (Balasubramanya 2019, Mukhamedova and Wegerich 2018). Remittances from both men and women are often invested in livestock, which contributes to increasing numbers, for example in Kyrgyzstan (Schoch et al. 2010). But there is little evidence that this is transforming the roles of women in term of livestock husbandry itself and it appears that in Kyrgyzstan at least, herding and negotiation for pasture access remain male-dominated (see Topic 2). Issues with land access and labour for herding may also explain why overall livestock, ownership in Tajikistan remains far higher in male than female headed households (Rocca et al. 2014).

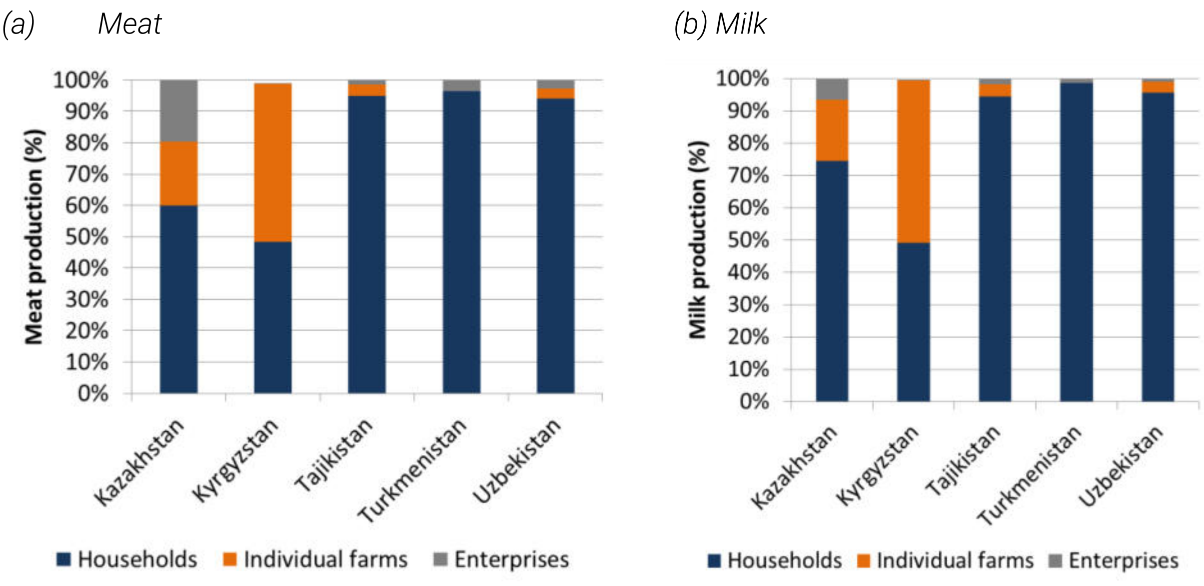
Farm structure and aggregate production

With the exception of beef production in Kazakhstan and Kyrgyzstan, total production of meat and milk now surpasses 1992 levels in all republics (Robinson 2020). However, Central Asia's population has also grown by almost 50% since 1991 and as will be discussed in Topic 5, the region is a net importer of livestock products.

In Uzbekistan, Turkmenistan and Tajikistan households account for over 90% of meat and milk production, with more participation from farms and enterprises in Kyrgyzstan and Kazakhstan (Figure 6). In Uzbekistan, the share of farmers in total production remains stagnant (Naumov and Pugach 2019) whilst in Kazakhstan these structures are now starting to account for most production increases; from 2006 to 2016 the share of households in meat production dropped from 82% to 60% and in milk production from 91% to 77% (Oshakbayev 2017).

[2] In a sample of 1855 farms in Southern Tajikistan (Balasubramanya 2019).

Figure 6. Total production volume of meat and milk by farm type in 2017



Adapted from Robinson (2020). *Sources:* Uzbekistan: Djanibekov and Petrick (2020); Tajikistan Statistical Agency of the Republic of Tajikistan (2018c); Kazakhstan Statistical Agency (2018); State Committee of Statistics of Turkmenistan (2018) Kyrgyzstan: National Statistics Committee of the Kyrgyz Republic (2018) and downloadable data tables.

Which restructuring policies for the SDGs?

In order to understand what kinds of farm structure may best further the SDGs, we must consider the purpose of livestock production and how this relates to SDGs on poverty reduction, zero hunger and economic growth. For example, if small farms are not the most efficient, then targets for farm productivity and efficiency under SDG 2 may not be entirely compatible with those under SDG 1 relating to secure tenure rights to land, targets for full employment under SDG 8, or with malnutrition reduction targets under SDG 2 (see Annex for list of targets and indicators).

These kinds of trade-off, which essentially concern farm scale, are important for SDGs because livestock are a commodity widely produced by smallholders, for which demand is rapidly growing. But if these are less efficient or if larger farms are better supported, then smallholders may be displaced by competition from larger-scale farms (Delgado et al. 2008). So we now turn to studies which compare the outcomes of restructuring policies by criteria of technical efficiency, employment and poverty reduction.

International literature suggests that large-scale farming by investor-held agro-enterprises is often less efficient than small individual farms as well as leading to poorer social outcomes in terms of employment and income (Binswanger et al. 1995, Petrick et al. 2013, Tomich et al. 1995). But in rapidly industrialising countries, optimum farm sizes increase with wages as economies of scale are needed to cover the capital investments required to reduce labour cost (Otsuka et al. 2016a). Delgado et al. (2008), reviewing livestock production (mostly pigs and poultry) at different scales in developing economies, found that small-scale producers may be more profitable per unit of input than larger producers, but that larger farms have higher overall profit-efficiency - which allows them to increase market share.

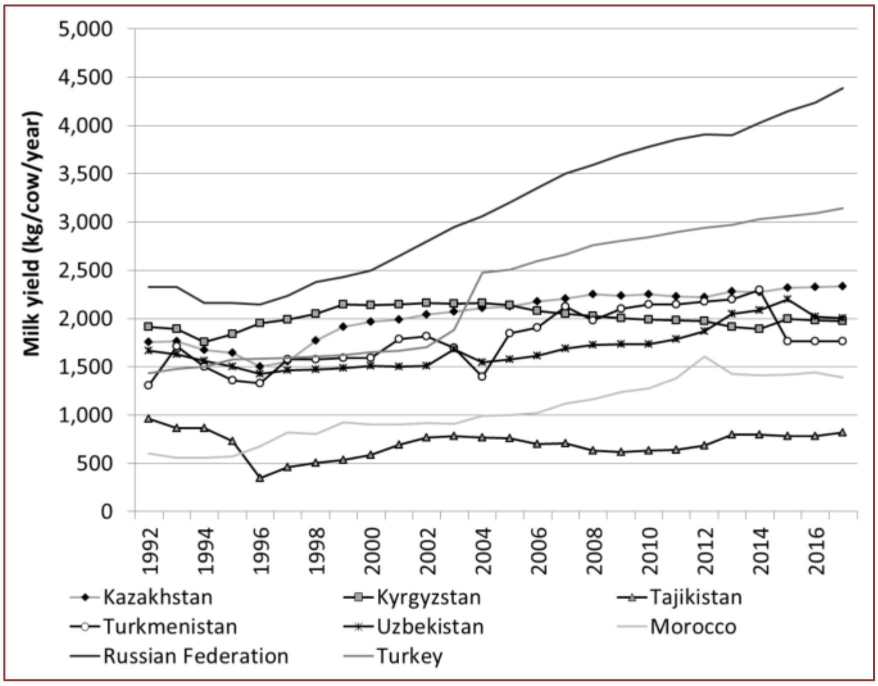
In Central Asia, Lerman and Sedik (2017b) have shown that individualization of agriculture is associated with the post-transition recovery and that, measured by crop yields alone, small individual farms outperform large enterprises. Early reform in this direction is said to explain the strong performance of Kyrgyzstan's agricultural sector in the 1990s compared to other countries in the CIS (Christensen and Pomfret 2008). Using broader measures of technical efficiency based on stochastic frontier analysis, decreasing returns to scale have been demonstrated in the Kazakh wheat production sector (Tleubayev et al. 2017). But this does not mean that very small farms are always the best driver of rural development. In northern Kazakhstan, the employment benefits brought by agribusiness, which has seen significant wage growth, have been substantial for the local population, who may prefer to work for a salary rather than attempt to make a living as a farmer (Petrick et al. 2013). Whilst optimum farm sizes may vary according to country and crop type, in Central Asia the perception amongst policy makers is that large scale agriculture is fundamentally superior (Lerman and Sedik 2017b).

To understand the impacts of reform on SDGs we now examine outcomes in the light of three metrics: individual animal performance; farm technical efficiency and rural living standards, important for goals of poverty, food security and economic growth.

(i) Animal performance

At the individual level, animal performance is largely determined by three components of pasture, fodder and genetics, which are discussed further in Topics 2, 3 and 4. Concerning milk yields, Central Asian states compare unfavourably with other emerging economies (Figure 7).[3]

Figure 7. Milk yields in Central Asian and selected emerging economies



Adapted from Robinson (2020). *Source*: FAOSTAT.

[3] In Europe and the US, yields are closer to 8000kg/cow/year, double that of the best performing country in Figure 7.

But averages can mask real differences between farm structures and scales: national statistics suggest that in Kazakhstan milk yields in enterprises, with access to pedigree animals and subsidies, reached almost double the national average at around 4,338 kg/cow/year in 2017 (Djanibekov and Petrick 2020). High yields in enterprises are also evident in Kyrgyzstan and Tajikistan (ibid.), but their performance is much poorer in Turkmenistan, where these (mostly state) structures record mean yields only half those of small private owners (Aganov et al. 2019).

Concerning beef production, FAOSTAT estimates suggest that mean cattle meat yields per carcass vary between 165 kg and 180 kg in the five republics (compared to 300 kg in France), with trends over the past ten years discernible only in Kazakhstan (positive) and Kyrgyzstan (negative). In Kyrgyzstan, mean weights of sheep at slaughter also continue to decline (from 42 kg in 2005 to 38 kg in 2014), probably due to both feeding and genetic factors (Tilekeyev et al. 2016).

Moreover, there are differences between farm types. In Kazakhstan, carcass weights of cattle slaughtered for export are said to have risen from 150 kg to 190 kg since 2010 (World Bank 2019) suggesting that performance in export-oriented enterprises is higher than the average of 175 kg reported by FAOSTAT. Live weights of cattle at slaughter reported by the national statistics agency are 402 kg in enterprises, 334 kg in farms and 322 kg in households (Kazakhstan Statistical Agency 2018). In Kyrgyzstan, equivalent figures are 298 kg for enterprises and 268 kg for both farms and households (National Statistics Committee of the Kyrgyz Republic 2018).

Survey data also suggest that, unlike crop yields, animal productivity tends to increase with farm scale, both between and within different types of farm structure (Robinson 2020). Within the category of individual farms in Kyrgyzstan, milk yield per cow is higher in larger structures, related to better feeding and higher prevalence of pedigree animals. In Uzbekistan, specialised livestock farms (holding large herds) have higher yields than mixed farms, with households having by far the lowest milk yields per cow (Naumov and Pugach 2019).

Little empirical work has been done in the region on the relative importance of different factors in determining animal performance. We have looked here at farm structure, or scale, which are proxy determinants representing a bundle of feeding, husbandry and genetic factors. The FAO Investment Centre (2010a) has noted in Kazakhstan that even under relatively good conditions potential live weights of local breeds are rarely reached, so nutrition is likely to be the key limiting factor. Zhumanova and Maharjan (2012) make similar observations in Kyrgyzstan, but husbandry issues such as housing and timing of calving also affect performance (Zhumanova et al. 2013). Breed quality is likely to become significant at higher nutritional planes.

(ii) Farm efficiency and profitability

The positive relationship of animal performance with scale does not mean that larger farms and enterprises are more efficient. Efficiency at the farm level measures output of product per unit of various production factors such as labour.[4] An understanding of efficiency can help avoid subsidisation or promotion of intrinsically inefficient operations, but very little work has been done on this topic in the region.

Work comparing technical efficiency of Kazakh beef cattle production between farms and enterprises using stochastic frontier analysis suggests that economies of scale are absent for

[4] This is also an SDG indicator (2.3.1 Volume of production per labour unit by classes of farming/pastoral/forestry enterprise).

beef production and that individual farmers have significantly higher technical efficiency than do enterprises (Petrick et al. 2018). Within the set of enterprises there may also be significant variability, depending on the extent of vertical integration (FAO Investment Centre 2010d). International experience suggests that vertically integrated beef production including stages from cow-calf to slaughtering and processing units is unusual for efficiency reasons (Nin et al. 2007) but more empirical work could be done on such ventures. Likewise, little evidence exists on efficiency or profitability of dairy enterprises other than farm margin comparisons in Kazakhstan, which suggest that some large dairy farms are highly dependent on subsides (FAO 2011a).

Amongst farmers engaged in mobile livestock production there is one sense in which economies of scale are extremely important. As discussed further under Topic 2, larger livestock owners are most likely to be able to move their animals to the best forage resources over the year, so that herd size is negatively associated with fodder costs per animal, and positively associated with mobility and weight gain (Kerven et al. 2004, Kerven et al. 2016, Mirzabaev et al. 2016a). Quantitative comparisons of different feeding and mobility strategies on farm productivity and financial indicators have thus far focussed largely on Kazakhstan.

(iii) Rural living standards

Reforms hastening the individualization of agriculture were seen as pro-poor, especially in Kyrgyzstan, where the process was relatively fair and contributed strongly to poverty reduction (Christensen and Pomfret 2008, World Bank 2003). However, even here land access is highly unequal, with the largest 10% of farms controlling 80% of arable land (Lerman and Sedik 2009). In other states it seems likely that inequality is even higher, especially between households and individual farms. It could be hypothesised that individual farms are specialised in agriculture whilst households, although holding a few livestock, are gainfully employed elsewhere. However, a number of studies have shown significant differences in annual income between farms and households in Uzbekistan (Lerman 2008) and in Tajikistan - where these differences are strongly connected to land access (Robinson and Guenther 2007, Robinson et al. 2010a). Access to land in Kyrgyzstan has been positively related to nutritional outcomes such as childhood gains in height and weight (Kosec and Shemyakina 2018). These findings are all significant for SDGs 1, 2 and 10.

In the Tajik study it was also found that, alongside land, lack of livestock ownership was strongly associated with poverty whilst those families selling agricultural or livestock produce are amongst the least likely to be poor, having a production surplus and access to markets (Robinson and Guenther 2007). On the other hand, Rhoe et al. (2008) did not find positive links between the probability of living above the poverty line and land or livestock holdings in Kazakhstan. This could be because (in some areas of the country at least) engagement in independent farming accounts only for a small part of income, and benefits from agriculture are more likely to accrue through employment in large agro-enterprises (Petrick et al. 2013). Less direct benefits from land and livestock access, such as loan collateral or insurance have not been addressed in the literature on Central Asia. Livestock are also very important for funerals, marriages and births as the family concerned must slaughter animals at these social occasions. By ignoring the insurance and social benefits, estimates of efficiency or rates of return underestimate the overall utility derived from livestock ownership (Binswanger and Rosenzweig 1986).

Major insights under Topic 1

The following points summarise the outcomes of reform for SDG trade-offs.

1. *Reform has resulted in extreme disparities in land and livestock distributions.* Households have the lowest land access and yet collectively own the majority of national livestock inventories. There is evidence from some republics that access to land and livestock are strong determinants of wealth, so reforms have had a significant bearing on patterns of rural income distribution observed today.
2. *Both livestock numbers and production have grown strongly in recent years, again with total product volume largest in households.* The proportion of dairy and meat produced in households is particularly high in Uzbekistan, Tajikistan and Turkmenistan.
3. *But there is variability between republics.* In Kyrgyzstan, both livestock and land access inequalities are much lower than in other republics and in Kazakhstan individual farms account for an increasing proportion of production. In Uzbekistan, disparities are higher but households may enter into contractual relationships with farmers to access land and inputs.
4. *Animal productivity is low but increases with farm size.* Animal performance, particularly regarding milk yield, is low compared to other emerging economies. Individual livestock performance is higher in larger scale operations, increasing both between the three main producer categories, and with size within the category of individual farms. This can be contrasted with crop yields and farm technical efficiency (mostly measured for crop production), which exhibit diminishing returns to scale, at least up to a point.

Research questions related to Topic 1

Research questions under Trade-off A. Commercialisation excludes smallholders.

1. *What is the evidence that restructuring has excluded smallholder access to value chains and thus incurred trade-offs for SDG goals?* Restructuring has resulted in a large number of poor but productive smallholders and a smaller number of larger commercial farms and enterprises. But within this pattern there is much variation. Highly skewed holding sizes such as those in Uzbekistan may have negative outcomes for land access indictors under SDG targets 1.4 & 2.3 in particular, but positive ones for value chain development and rural employment (target 8.2). Without land consolidation, more equal distributions such as those in Kyrgyzstan may affect development of commercial livestock production. More rigorous work on the trade-offs associated with different farm size frequency distributions should be conducted.
2. *Is the relationship between households and farms, or between small and large farms mutually beneficial? What can smaller actors gain from the larger ones?* There is evidence that in some countries, access to resources is less unequal (target 2.3) than it first appears as households may enter into contractual relationships with farmers and enterprises for access to land and services. References reviewed here have identified various arrangements on cropland and pasture, but little is known about the outcomes of these for the parties involved in terms of SDGs 1 and 2 in particular.
3. *How do different types of livestock farms compare in terms of productivity and intensity of resource use?* In the livestock sector, little work on technical efficiency (relevant to

target 2.3 on agricultural productivity and 8.2 on economic productivity) has been undertaken. Such analysis can help identify the optimal size of farming operations, but could also be used to compare farms with different levels of intensification, pastoral mobility and vertical integration (see also Topic 5 on value chains). A classification of farming systems which goes beyond farm structure (HH, IF, E) and scale could be used to identify different types of farming system or strategy for comparison. Such a classification can also be used to compare the environmental footprint (targets 6.4, 13.2 & 15.3) alongside economic indicators of farm performance, (targets 2.3 & 8.2; see Topics 2 & 3).

4. *How has restructuring affected the determinants of animal performance?* Focusing on individual animal performance, more work should be done to understand determinants of milk yields and carcass weights and to examine allocation of different factors of production to animal husbandry. Such analysis will also help understand whether projects and policies prioritising individual performance are considering the trade-offs which such performance entails in terms of costs and efficiency per unit of product or hectare of land (targets 2.3 & 2.4).

5. *To what extent have government policies discriminated against smallholders?* This question looks at whether subsidies, credit and land reform policies exacerbate the inequalities described here, and at whether promoting the most efficient operations (if these are not the smallest) would incur trade-offs with SDGs 1 on poverty, 2 on food security - which includes targets for access to the factors of production, and 10 on inequality (see Topic 8). In some countries the likely impacts of specific policies, such as clusters in Uzbekistan or the apparent new focus on individual farms for beef production in Kazakhstan, should be explored.

Topic 2. Extensive livestock production: sustainable grazing systems

Global rangelands and the sustainable development goals

This topic reviews SDG trade-offs related to livestock production on natural pastures, looking in particular at interlinkages between pastoral property rights, livestock mobility, farm incomes and pasture condition.

Natural rangelands cover around 40% of the earth's terrestrial land surface, more than any other type of land (de Haan et al. 2010, Steinfeld et al. 2006). Although they support a small proportion of the world's population, 35% of the world's sheep, and 16% of cattle and buffalo are grazed on these lands (Reid et al. 2008). Creation of new grazing land from forest has had catastrophic effects on biodiversity and GHG emissions (Herrero et al. 2009), but the majority of the world's rangelands are found on marginal land which cannot be used for cropping and here, pastoralism is an efficient way of turning sunlight into food (Reid et al. 2014). Rangelands have co-evolved with grazers and moderate grazing can have limited negative effects on biodiversity, or even promote it, whilst providing ecosystem services through vegetation cover and carbon sequestration (Toutain et al. 2010). The exploitation of distant pastures can also be a cheaper alternative than purchase or production of fodder, or a livelihood option for those without access to arable land (Fernández-Giménez and Ritten 2020, Ripoll-Bosch et al. 2013).

But high grazing pressure can cause land degradation, leading to loss of biodiversity, soil carbon and reduction in the economic potential of these lands. Global estimates of land degradation extent vary hugely, with equally wide disagreement in their spatial distribution (Gibbs and Salmon 2015). Estimates for the proportion of arid rangelands affected ranged from 20% (Oldeman et al. 1990) to 70% (Dregne and Chou 1992) for the 1980s, whilst more recent methods suggest a figure of 26%, with a loss of around 20% of net primary productivity per year on these lands (Zika and Erb 2009). But it can be difficult to disassociate the effects of livestock production from those of long term climatic trends. In areas of the world with high rainfall variability there have been debates about whether it is grazing or erratic rainfall which drive fluctuations in vegetation production (Ellis and Swift 1988, von Wehrden et al. 2012). More recent concerns about the environmental impacts of grazing have focussed on GHG emissions, which are much higher in grassland-based systems than under more intensive management (see Topics 3 & 7).

Globally, there seems little doubt that rangeland systems are under pressure. Livestock numbers in arid lands are increasing strongly (Godde et al. 2018). Traditional systems of rangeland management depend on animal movement in order to track forage in time and space (Coughenour 2008). But mobility is increasingly hampered by fragmentation of grazing systems (Galvin et al. 2008). Infrastructure development, encroachment of cropping, market integration and land privatisation have all contributed to these changes (Behnke 2008). In arid systems, individualisation of pasture tenure, enclosure, and reduction in the ability of livestock to match variable or shifting grazing resources, has been associated with land degradation (Li et al. 2007) and a reduction in system output (Boone and Hobbs 2004, Hobbs et al. 2008). International debates around socially and environmentally sustainable pastoralist systems focus largely on property rights systems and institutions for governance which can resolve the 'pastoral paradox' – whereby livestock owners in arid environments need both secure and flexible access to rangelands (Fernandez-Gimenez 2002, Reid et al. 2014).

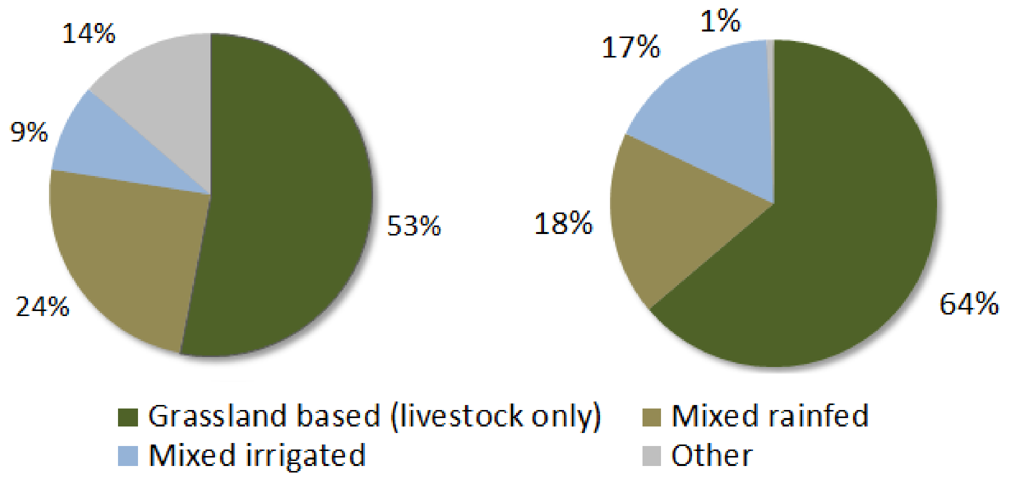
The significance of Central Asian rangelands

From the point of view of the above discussions, Central Asian rangelands are highly significant for SDG attainment. Firstly, they are vast, comprising from 81% (Tajikistan) to 95% (Turkmenistan) of all usable agricultural land in the five republics (Gintzburger et al. 2005). They offer a wide variety of vegetation types, which can be exploited at different seasons. Outside highland areas and the plains of northern Kazakhstan, where rainfall is above 300mm per year, cropping is only possible under irrigation, thus across much of the region livestock production is the only viable economically productive land use option available. This explains why over 50% of the land area of the region is dominated by grassland-based livestock production systems (Figure 8a), with the majority of poor livestock keepers residing in these areas (Figure 8b).

Figure 8. Central Asian grazing systems

(a) Proportion of total area covered by different agricultural systems

(b) proportion of poor livestock keepers in each system.



Source: Robinson et al. (2011), Thornton et al. (2002).

Grassland based-livestock systems: less than 10% of the total value of production comes from non-livestock farming activities. More than 10% of the dry matter fed to animals is produced on the farm, and annual average stocking rates are less than 10 temperate livestock units per hectare of agricultural land. *Mixed farming systems (MFS)*: either more than 10% of the dry matter fed to animals comes from crop by-products or stubble, or more than 10% of the total value of production comes from non-livestock farming activities. *Rainfed MFS*: more than 90% of the value of non-livestock farm production comes from rainfed land. *Irrigated MFS*: more than 10% of the value of non-livestock farm production comes from irrigated land.

In the following sections we deepen the analysis of land reform which we began in Topic 1, looking at how households and farms access pasture, and implications for food security, income and pasture management. The extent to which livestock are mobile is a key determinant of animal productivity, and also affects patterns of grazing pressure. We review the evidence on the influence of grazing and other processes on the condition of pasture resources.

The breakdown of Central Asian grazing systems

Grazing systems were traditionally based on the exploitation of temporal and spatial variability in pasture quality and quantity, which allowed herders to feed their herds on natural grazing virtually all year around (Fedorovich 1973, Ferret 2014). Soviets built on traditional migratory patterns using geo-botanical and meteorological assessments to construct scientifically planned grazing regimes, augmented by massive well building programmes to bring additional pasture into use (Elemanov 1957, Robinson et al. 2016, Shaumarov and Birner 2013). Although substantial winter feed was provided compared to traditional systems, the major rational was the lower cost of mobile compared to sedentary livestock production (Shaumarov and Birner 2013). Rich summer pastures support rapid weight gain whilst use of winter pastures (on which vegetation is often free of snow through south-facing exposure or dominance of large shrubby species) greatly reduces feeding costs (Kerven et al. 2004).

These systems, formerly benefitting from top-down pasture use planning and the large scale of state farms, broke down during transition and have only partially recovered; many previously grazed desert pastures now lack working water supply for stock, rendering them unusable without large-scale investment (Schillhorn-van-Veen et al. 2004, Yusupov et al. 2010). In Kazakhstan, estimates of total available pasture actually used range from 17% to 48% (Broka et al. 2016b, Hankerson et al. 2019, Issayeva and Bakhralinova 2020, Tazhibaev et al. 2014), much of it grazed at very low intensities (Hankerson et al. 2019). It has been estimated that a minimum of 31% increase in beef production on 2015 would be possible through more intensive use of currently accessible pasture, and much more with utilization of distant pastures (ibid.).

Some pastures in mountainous republics were also abandoned due to access issues (Farrington 2005) and migrations which crossed republic borders either ceased or are now the subject of conflict (Murzakulova and Mestre 2016). This loss of movement has led to overgrazing on village pastures and other non-remote wintering areas (e.g. Alimaev et al. 2008, Hoppe et al. 2016). In Turkmenistan and Uzbekistan many livestock owners do not even use pastures, grazing their animals all year around in the irrigated zone, between fields, along canals and on stubble after harvest.

However, larger herders rapidly returned to mobile husbandry due to the necessity to feed their animals (Kerven et al. 2016). Some smaller herders resuscitated traditional institutions such as *kezu* and *bada* in Kyrgyzstan (Steimann 2011), *chekene* in Turkmenistan (Lunch 2003) and *novad* in the Tajik Pamir (Watanabe and Shirasaka 2018), which are mechanisms of pooling livestock to collectively cover migration and herding costs.

Grazing patterns and access to pastoral resources

Pastoral land tenure

Figure 5 (In Topic 1) presents official statistics on legal title to pasture in Central Asian countries, suggesting almost zero formal access for households in most republics. However, even more than arable land, physical access to grazing land cannot be inferred from statistics. In Turkmenistan (and Uzbekistan to some extent) livestock owners of all types graze on land formally allocated to state enterprises - sometimes with considerable freedom of access (Behnke et al. 2016). In Kazakhstan and Tajikistan, landless households or farmers may send animals with relatives having formal access to pastures or sublease pasture privatised by others (Halimova 2012). Moreover, the data presented indicate large areas of unallocated state-owned pasture, which includes both state reserve lands and land belonging to forestry departments. In all republics, pasture in the latter can be used for grazing under temporary contracts. Much of the state reserve is truly abandoned due to loss of water supply infrastructure, lack of access, or both, but an unknown proportion is certainly grazed. In Tajikistan in particular, remaining reserve lands are used as summer pastures for community grazing (Robinson et al. 2010b).

In all the republics, the initial approach taken to reform was one of pasture privatisation or leasing – an individualisation of property rights. This occurred despite the re-emergence of collective herding systems based on kinship, residence and historical precedent. In some cases land codes designed with arable reform in mind were simply applied to pastures by default, but the idea that individuals must be legally bound to individual parcels of land in order to manage them properly was also influential. International organisations on the other hand often promoted common property regimes, using environmental arguments based on a rather different set of ideas about pastoral systems, stressing the importance of mobility and flexibility (Robinson et al. 2017).

In Tajikistan, the initial restructuring programme (applied through the Law on Dekhan Farms) was based on permanent heritable use but the Land Code also includes leasing arrangements. Receipt of shares was not automatic and in some areas a small number of people were able to privatise large areas of pasture (Halimova 2012). The 2013 Law on Pastures added an option for 'communal' pasture ownership to existing leasing and permanent use arrangements, implying that pasture could be provided to users' associations established at the village level (Jaborov et al. 2017). But statistics do not indicate how much land has been allocated for common use since that legislation was passed (and hence these areas are missing from Figure 5). Procedures are not transparent and it is unclear how district authorities decide whether to allocate pasture to users' associations or private farms (ibid). Reports from donor projects suggest that some users' associations have received land certification, whilst others lease or sublease from private individuals (Pasture Management Network of Tajikistan 2015, Weperen 2016). In the highly researched Eastern Pamir, tenure patterns evolved slightly differently; with pastures transferred from state farms to so-called 'farmers associations' which were to allocate pastures to users on a seasonal basis (Hangartner 2002). In reality, certain valuable pastures were claimed by large livestock owners who took advantage of confusion about land rights to exclude others (Vanselow et al. 2012b). In other areas they are used as de facto common property or (more rarely) have been formally privatised by individuals (Watanabe and Shirasaka 2018).

In Uzbekistan households hold 93% of livestock units, yet have no formal access to pasture, which are held in quasi-state enterprises (*shirkat*) and individual farms. This mismatch has been exacerbated by two processes - the Livestock Development Program of 2006 that supported rural households to increase their livestock holdings, and the forced consolidation of farms concentrating land in a still smaller number of hands. Yet, as in Tajikistan, access to pastures by households and farms is much higher than statistics suggest. Donor project reports demonstrate that households come to various grazing arrangements with *shirkat* authorities (Fischer-Zujkov et al. 2011, Robinson et al. 2012). These enterprises lack the capacity to monitor their vast pastures and have no legal basis to exclude other users (Shaumarov and Birner 2013). Much of the land reserve or forest lands is used informally (Naumov and Pugach 2019), as illustrated in the case of summer mountain pastures by Cariou (2002). Whatever the informal mechanisms, recent surveys suggest that households have very little access to remote pastures and migratory systems are practised only by large livestock owners (Naumov and Pugach

2019). Uzbekistan introduced a Law on Pastures in May 2019, but it is unclear whether the new law will strengthen rights to pastures for households and farms.

In Kyrgyzstan, a leasing mechanism was initially introduced for pastures (Kasymov and Thiel 2019, Undeland 2005). However, it quickly became clear that this system suffered from a number of drawbacks. Collective herding groups characterised by fluid membership were not legal entities and thus found it difficult to register contracts, some leaseholders stopped moving to summer pastures and excluded community herders from autumn-spring pastures, leading to conflicts (Kasymov and Thiel 2019). Transaction costs were high as separate contracts had to be concluded for each seasonal pasture and the system brought in little revenue, as many pastures continued to be used informally (Steimann 2011, Undeland 2005). These problems, Kyrgyzstan's existing experience with autonomous local power structures, and reliance on foreign funding facilitated an experiment in common property resource management (CPRM), financed and designed through World Bank investments (Robinson et al. 2017)..

The resulting 2009 Law on Pastures repealed leasehold contracts. Pastures are now allocated to village governments and managed by Pasture User Associations (PUA) through annual allocation of pasture tickets to members. There has been some research into the administrative quality, inclusivity and legitimacy of PUAs (Crewett 2015, Dörre 2015, Shigaeva et al. 2016). Kasymov and Thiel (2019) found that leaseholds had reinforced claims based on historical and power relationships, whilst the 2009 legislation initiated re-negotiations among pasture users in which collective herders had an improved position. But wealthy livestock producers can exert powerful influence on Pasture Committees, the executive bodies of PUAs (Crewett 2011). There is evidence that, rather than taking on the role of democratic organisations representing members' interests, PUAs may be perceived as just another organ of local government control (Shigaeva et al. 2016). Female livestock owners rely on male relatives or sons to access remote pastures as they have weak negotiating positions within PUAs and are unlikely to receive high quality land. In pasture committees men tend to focus budgetary discussions on infrastructure maintenance rather than on investments in electricity, light and clean water in remote pastures which would facilitate in particular the kind of work done by women in those areas (Scalise and Undeland 2016). Women are likely to lose a higher proportion of grazed animals to death or ill health than their male counterparts (ibid.).

In 2016, the debate about pasture management was relaunched, and a proportion of pasture user fees are now paid to central government rather than to local PUAs. There is still a lobby of large commercial livestock producers which claims that the CPRM system is a barrier to the development of the sector. The question arises as to whether the new system prevents private investment in pasture infrastructure, in particular those types not generally considered to be public goods – such as barns. The work by Kasymov and Thiel (2019) suggests that the social position of large individual farmers protects their interests in this respect but more research is needed to explore trade-offs between sector commercialisation (SDG 8) and access to pastures by smallholders (SDG 1 & 2).

In Kazakhstan, pastures were subject to the same laws as arable land, and the major modality of use is therefore the 49 year leasehold. In addition, land around villages is allocated to local municipalities for common grazing, constituting 12% of total pasturelands (Figure 5). The area of non-allocated state reserve area is now decreasing as pasturelands are leased out to individual farms (Robinson et al. 2012), but by 2019 it still included 40% of all pasturelands (Akisheva 2021). Although some non-leaseholders access pastures through sub-lease or collective herding initiatives, certainly a large proportion of the 60% of livestock held in households (as well as many animals belonging to smaller farms) use only village lands. Leasing markets remain inefficient, with no straightforward process for transfer of leaseholds back to districts for redistribution or directly between farmers. In response, the Kazakh government is currently attempting to identify and expropriate unused leaseholds for redistribution. A 2017 Law on Pastures introduces the idea of district level pasture use planning, including provision of pasture to those currently lacking access. But there are few legal instruments to realise this (Robinson et al. 2021).

In all republics, grazing on forest lands is managed by the forest department, usually under short-term leaseholds. These lands form an essential part of grazing systems, in high mountain forests in the summer or on desert saxaul-dominated areas in the winter. Experiments with collaborative forest management have been made in Kyrgyzstan (Carter et al. 2010) and Tajikistan (Kirchhoff and Fabian 2010). Kyrgyzstan has gone furthest in terms of development of legal frameworks for grazing on this land, and is experimenting with the integration of forest lands into grazing systems as part of the broader common property system in place in that republic (CAMP Alatoo Public Foundation 2020).

The economics of livestock mobility

The above review suggests that most property rights systems shut smallholders out of formal access to remote pastures. However, whilst common property systems such as that in Kyrgyzstan may improve the rights of smallholders to pasture on paper, they are unlikely to be sufficient to re-create the extensive grazing systems of the past. Research has shown that both power relationships and economic barriers to pasture use may be more important for many households and farms (Crewett 2012, 2015). The literature reviewed in this section suggests that these economic barriers are strong for small farms but give way to incentives for mobility at larger herd sizes.

In Kazakhstan, economic gains associated with mobility are realised through low fodder costs and higher animal weight gain (Issayeva and Bakhralinova 2020, Kerven et al. 2004, 2006, Milner-Gulland et al. 2006). But fixed capital costs associated with movement including transport and investment in infrastructure can be covered only by those owning large numbers of animals (Kerven et al. 2004). Pasture condition where the animals are based (determined by total stocking rates) is also an important push factor determining whether animals will move, as demonstrated in Turkmenistan (Behnke et al. 2016) and amongst ethnic Kazakhs in China (Liao et al. 2014). This push factor, and the pull of distant pastures, are likely to be more significant in drought years although this has not been widely demonstrated. In much of Central Asia, inter-annual rainfall variability is relatively low compared to other regions of similar aridity (Gintzburger et al. 2005), so migratory patterns tend to be stable from year to year. An exception is Turkmenistan, where drought is common and movement patterns vary as a function of rainfall (Behnke et al. 2008).

Overall, propensity to move is a function of the quality of local pasture resources, fodder costs (or availability) and herd size. Those owning large numbers of animals are likely to use more different types of pasture over the year and to migrate further (Behnke et al. 2016, Kerven et al. 2016, Mirzabaev et al. 2016a, Robinson et al. 2016). Where collective herding is widespread, similar economies of scale are created amongst smallholders, allowing mass movement of village animals to access remote pastures, particularly high mountain summer areas (Kasymov and Thiel 2019, Robinson et al. 2010b, Watanabe and Shirasaka 2018). Use of winter pastures (through establishment of outlying bases) is particularly expensive due to the investments in human and animal shelters required.

Modalities for improvement of infrastructure in pastures include direct investments by government, subsidies for well building (such as in Kazakhstan), and investments by PUAs as in Kyrgyzstan (funded by pasture use fees, government and donors). Little research has been conducted on the relative effectiveness and sustainability of different land tenure models on such investments (Zhumanova et al. 2016).

Pasture condition: grazing and land conversion

Much has been written on the deterioration of pasture condition, both globally and in Central Asia. In view of SDG 15 and in particularly indicator 15.3.1: *Proportion of land that is degraded over total land area*, we examine the major drivers of change on rangelands: land conversion and grazing, looking for evidence of degradation. We are particularly interested in relationships between degradation and land reforms, poverty and livestock productivity.

Land conversion

Conversion from pasture to arable land leads to loss of topsoil through wind and water erosion and loss of carbon to the atmosphere, but these impacts may be reversed if the cropland reverts to pasture (see Topic 7). The environment damage associated with the virgin lands campaign in northern Kazakhstan has been well documented (e.g. Pryde 1991). But since 1991 large scale cropland abandonment has occurred on these lands (Hölzel et al. 2002) and by 1998 the area sown to crops had decreased by 38% (Suleimenov and Oram 2000). Although abandonment initially resulted in poorly productive pastures dominated by weeds (Rachkovskaya et al. 1999), if undisturbed, steppe associations similar to those of the original 'virgin' steppe may reappear within 20 years (Rachkovskaya and Bragina 2012).

Since the time of 'peak abandonment' in the late 1990s, some of these lands have been replanted to grain. Between 1999 and 2008 in the provinces of Akmola, Kostanai, and North-Kazakhstan, in which 80% of Kazakhstan's wheat is produced, agricultural land use increased by about a third, bringing five million ha of cropland back under the plough (Petrick et al. 2013). Recultivated lands were the most productive, and the last to be abandoned, whilst the 14 million ha remaining abandoned areas are on marginal lands, quickly taken out of production after 1990 (Dara et al. 2018, Kraemer et al. 2015).

A number of authors recommend intensification of production on the best land, setting aside the abandoned marginal areas for livestock production rather than re-cultivation, for both environmental and economic reasons (Baumann et al. 2020, Dara et al. 2018, Kamp et al. 2015). Many steppe wildlife species depend on grazing, which also reduces fire incidence (Dara et al. 2019) and hastens reversion of cropland to species-rich steppe environments (Brinkert et al. 2015). Mirzabaev et al. (2016b) suggest that these areas may provide more value through provision of ecosystem services than as croplands, but that these benefits are not always internalized locally, so that policy interventions may be required to preserve them. Gains in carbon sequestration are particularly important (see Topic 7).

In contrast, opposite and less well studied trends of pasture conversion to arable land have been reported in southern Central Asia, particularly in Tajikistan. Here, steep rainfed lands were planted to wheat for household consumption, resulting in very high erosion levels (Ministry of

Nature Conservation of the Republic of Tajikistan 2001). Such lands are quickly abandoned, following which soil quality remains low for long periods (Wolfgramm et al. 2007). Nationally, it has been estimated that conversion to rainfed crops decreased the physical area of pasture by up to 15% (Umarov 2019). There is anecdotal evidence that such land may already have been progressively abandoned as alternative income sources, such as remittances from Russia, increased in importance in the 2000s.

The magnitude of this process at the regional level is poorly documented. Sommer and Pauw (2011) found that from 1982 to 2000 the conversion of cropland to grassland (mostly in northern Kazakhstan) was matched by conversion of grassland to cropland elsewhere in the region. Positive net change in cropland in Uzbekistan and Turkmenistan has been detected during the 2000s, although this has not been broken down into irrigated and rainfed lands (Mirzabaev et al. 2016b). These studies depend on detection of land cover change using low resolution images and global land cover products with high margins of errors, so may not reflect reality on the ground (de Beurs et al. 2009).

The definition and detection of land degradation

There is a common understanding of the meaning of land conversion. But degradation of existing pasturelands through grazing is a far more nebulous concept. Overall, 13% of rangelands in Kazakhstan; 74% in Kyrgyzstan, 90% in Tajikistan, 50% in Turkmenistan and 42% in Uzbekistan are said to be degraded (2006 reports by the Central Asian Countries Initiative for Land Management (CACILM) cited in Mirzabaev et al. (2016a)[5]. However, differing definitions (Box 1), measurement methods and the level of severity chosen for reporting have led to a wide range of estimates (Robinson 2016).

Box 1. Definitions of land degradation

"*Land degradation is the reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest or woodlands resulting from natural processes, land uses or other human activities and habitation patterns such as land contamination, soil erosion and the destruction of the vegetation cover*" (United Nations 1997).

Livestock cause soil erosion and transformation of vegetation cover. Metrics used to measure the latter range from botanical changes in species diversity, net primary productivity (NPP), through production of edible biomass to economic output from the resource. These different metrics may also reflect differing perceptions of degradation between scientists, policy makers and pasture users. For example in Kyrgyzstan users' assessments of pasture condition tend to be more positive than those of scientists or policy makers (Levine et al. 2017, Liechti 2012). This difference may be explained by loss of knowledge or alienation of users from the natural resource, or it may be because they are more interested in output of livestock products from the system, rather than pasture quality per se. Whilst the two are obviously linked, the relationship is not linear.

Jones and Sandland (1974) showed that the stocking rate corresponding to maximum weight gain per head of cattle is well below that corresponding to the maximum production of meat

[5] National working groups of the United Nations Convention to Combat Desertification (UNCCD) elaborated national programming frameworks in each republic.

per hectare. By implication, the optimum stocking rate for production *per unit of land* will transform the vegetation more than a lower stocking rate favouring maximum weight gain *per animal*. Studies in the semi-arid USA suggest that moderate grazing corresponding to 35–45% use of forage produces more meat per hectare than light grazing, despite lower vegetation productivity and lower gains per animal (Holechek et al. 1999). Someone measuring total (edible) pasture productivity or looking at changes in biodiversity could classify vegetation under this type of moderate grazing as degraded. It should be stressed here that in Central Asia most studies concern vegetation condition rather than the long term ability of pastures to produce economic output (Robinson and Milner-Gulland 2003).

In addition to problems of definition, there are a number of methodological issues in measuring degradation of vegetation cover (Jamsranjav et al. 2018). These include: (i) difficulties in disentangling the impacts of livestock raising from other factors, such as climate; (ii) correction for offtake by livestock (some studies measure immediate seasonal effects of livestock offtake, not the long-term impacts of grazing); and (iii) accounting for pasture quality (studies measuring biomass or NPP alone do not distinguish increases in edible vegetation from proliferation of inedible species (Zhumanova et al. 2018)).

Studies which overcome these issues are often expensive and thus cover small areas or are only relevant locally, whilst scaling up is problematic. Remotely sensed indices of vegetation are used in many studies (Box 2). But whilst medium resolution images (pixel size of 15-30m) can detect specific processes at the local level such as vegetation change around wells and ploughing of pastures (Karnieli et al. 2008, Wolfgramm et al. 2007), coarser scale images may be largely capturing climatic processes (de Beurs et al. 2009).

Box 2. Use of remotely sensed vegetation indices in pasture monitoring

Vegetation indices such as the Normalised Difference Vegetation Index (NDVI) are essentially indicators of vegetation 'greenness' generated from multi-spectral satellite imagery. NDVI products have been demonstrated to have empirical relationships with vegetation, biomass, cover and Net Primary Productivity (NPP) (Pettorelli et al. 2005). Whilst NDVI itself can rarely indicate different land cover types, phenological signals over the year may be used to distinguish between forest, cropland and grassland. However, NDVI is not an indicator of vegetation quality nor can it easily be used to distinguish between different vegetation associations on rangelands. This is important, as vegetation palatability and protein content can be more important than overall biomass in pasture selection by both wild animals and livestock herders.

Bearing the above issues in mind, what can we say about the impacts of livestock production on pasture condition in Central Asia? Recent studies are of two types: local studies including some fieldwork, sometimes combined with remote sensing, and regional studies, usually employing NDVI and very little in the way of ground data. Most studies reviewed here look at vegetation condition alone, without considering the above discussion about what the transformed vegetation communities mean for animal production.

Studies measuring land degradation

Local studies demonstrating spatial impact of grazing: A number of studies use botanical data to describe the spatial influence of grazing on vegetation diversity and productivity, in particular around wells and settlements (Alimaev 2003, Alimaev et al. 2008, Borchardt et al. 2011, Kanchaev et al. 2003, Rajabov 2009). Studies in Naryn oblast of Kyrgyzstan and the Tajik Pamir found degradation of vegetation and soils in village and proximate winter pastures, combined with underuse of remoter areas (Hoppe et al. 2016, Vanselow et al. 2012a, b). There are also large regional differences, with risks of overgrazing where livestock numbers have remained high in Turkmenistan (Gintzburger et al. 2009) and much lower risk in desert areas of Kazakhstan (Gintzburger et al. 2011).

Local studies demonstrating trends over time. A number of studies documented range recovery in Kazakhstan following the collapse in livestock numbers (Alimaev 2003, Karnieli et al. 2008, Robinson 2000, Sadvokasov 2000, Stogova 1999). Dara et al. (2020) using Landsat imagery to cover a large part of northern Kazakhstan demonstrate that, despite some recovery in livestock numbers, the grazing footprint is still much lighter today than in the 1980s. Increases in vegetation cover and biogenic crusts (lichens which indicate undergrazing) have been detected in the Karakum desert, attributed to state gas provision (and the associated decreased need for firewood (Kaplan et al. 2006)), and abandonment (Orlovsky et al. 2004). Other studies demonstrate clear deterioration over time, particularly on near-village areas and winter pastures (Mirzabaev et al. 2016a). After controlling for climatic variability, Eddy et al. (2017) found negative NDVI trends in Naryn oblast of Kyrgyzstan, mostly in populated areas at lower elevations, whilst in the southern Karakum degradation around wells increased between 2000 and 2008 (Ji 2010).

Regional studies: Large scale analyses exclusively employ remotely sensed products to examine NDVI trends or land cover changes. Several studies found increases in NDVI or greening of barren lands up to the early 2000s, followed by declines, particularly over western areas of Kazakhstan, Uzbekistan and Turkmenistan (Lioubimtseva 2007, Mirzabaev et al. 2016b, Mohammat et al. 2013, Zhou et al. 2015). Another consistent finding is a general 'browning' trend (decrease in NDVI) in northern Kazakhstan, which has accelerated over the last decade (de Beurs et al. 2009, de Jong et al. 2012, Mirzabaev et al. 2016b, Mohammat et al. 2013, Zhang et al. 2018). Most authors attribute this trend to climatic factors, including precipitation decreases (particularly in summer) and a recent cooling trend in spring. But the phenomenon has also been detected in studies which attempt to correct for precipitation variability (Bai et al. 2008, Robinson 2016). Le et al. (2014) detected long term climate-corrected NPP decreases affecting 15% of the area of Tajikistan, 38% of Kazakhstan and Kyrgyzstan, 23% of Uzbekistan and 17% of Turkmenistan (Mirzabaev et al. 2016a). The conclusions drawn are that these trends are due to non-climate-related anthropogenic factors such as grazing or land use change. However, the processes behind these figures across such broad scales remain speculative.

A number of studies attempt to measure the cost of land degradation (of all types) in Central Asia, notably as part of the Economics of Land Degradation (ELD) initiative (Quillérou et al. 2016). Mirzabaev et al. (2016b), estimating cost of lost ecosystem services from land cover change, suggest that over 30 years, costs of land degradation are five times higher than costs of potential actions to avert it. But this figure does not include transaction costs of implementing SLM-oriented reforms, nor of adopting technologies.

Sustainable land management

Identifying property rights systems most likely to foster good pasture management (usually manifested through livestock mobility) is the most often discussed approach for combating overgrazing (Mirzabaev et al. 2016a) and this subject is discussed at length in the above section on land tenure. But well-designed attempts to compare environmental impacts under different management regimes such as the study by Jamsranjav et al. (2018) in Mongolia, are missing from the Central Asian literature.

The extent to which *individual* livestock producers apply management techniques other than seasonal movement are poorly understood. Donors and governments often promote SLM technologies on pastures as part of projects[6], but there is little information on uptake. We discuss the two most commonly promoted interventions in more detail below.

Re-seeding: Pasture improvement by seeding of wheat-grass (*Agropyron* spp.) was common during the Soviet period and recent projects promoting this on abandoned crop lands for hay production suggest positive returns on investments and uptake by farmers (World Bank 2010). Sowing of *Agropyron* mixed with other species has hastened the return of high quality grazing lands on abandoned cropland (Mirzabaev et al. 2016a, Schillhorn-van-Veen et al. 2004). However such overseeding is not always appropriate and may even be harmful in semi-desert areas (Dimeyeva et al. 2017). In such arid zones, seeding with native legumes such as *Astragalus*, *Alhagi, Lathyrus* and *Glycyrrhza* spp. and salt tolerant plants (Toderich et al. 2008) may be more appropriate and cultivation of halophytic plants using drainage water is said to have significant potential in Turkmenistan (Mirzabaev et al. 2016a). Also in that country, it has been estimated that the value of pasture land (in terms of output per hectare) can be doubled in eight years through artificially planted vegetation and creation of surface furrows to capture surface water (Nepesov and Mamedov 2016). But these studies lack full details of costs and benefits of these interventions. In poorly productive arid environments, gains may be small compared to labour investments required.

Rotation: In the literature on pastures in Central Asia there is widespread confusion between the words migration and rotation. *Rotation* is the movement of animals between paddocks or parcels of pasture (often fenced) in the same general area, to allow vegetation recovery between periods of grazing. Central Asian systems traditionally depended on *migration*, in which animals are moved between geographically separate pastures, usually having different vegetation types, although it has been suggested that Kazakhs traditionally practised forms of rotation *within* these seasonal pastures (Zhambakin 1995). Rotation experiments were conducted in the Soviet period, when this method was known as the *zagon* system, conceived as a way of using a single semi-arid ecotype all year around – i.e. as a substitute for mobility (Zhambakin 1995). More recently, international projects have tested short term rotation systems on single season pastures (Isakov and Miinazarov 2019), but full results have not been published. Globally, range science suggests there is little evidence that short rotations in arid environments have any advantages over continuous grazing (Briske et al. 2008, Holechek et al. 1999). Inter-annual rotations with year-long resting of pastures between use may be more beneficial to vegetation, but

[6] See also the World Overview of Conservation Approaches and Technologies (WOCAT) initiative in particular, including a number of Sustainable Land Management (SLM) interventions which have been tested in Central Asia https://www.wocat.net/en/.

resulting increases in annual productivity may not compensate for the area of vegetation taken out of use annually (Westerberg et al. In press).

Mirzabaev et al. (2016b) used survey data from across the region to explore factors associated with adoption of SLM technologies. These included market access, access to extension, learning from other farmers, private land tenure among smallholders, livestock ownership among crop producers, lower household sizes and lower dependency ratios. It is notable that more than one third of surveyed households did not use any SLM technology, and that most frequently used techniques concerned soil fertility improvements and more efficient irrigation techniques on arable land rather than interventions on pastures.

Major insights under Topic 2

1. *The vast majority of Central Asia's land area is covered by rangelands, offering a wide variety of vegetation types which can be exploited at different seasons through migratory systems.* Aridity makes livestock production the only viable land use on much of this land and extensive grazing can be a cost-effective alternative to fodder production where cropland is limited. But whilst moderate grazing is compatible with many SDG goals, heavy or sedentary stocking can have negative effects on vegetation, soils and biodiversity. Extensive livestock production on arid rangeland is also a major source of GHGs caused by enteric fermentation of poor quality roughage.
2. *Trade-offs between the economic benefits of using pasture for grazing, food security and GHG emissions are less stark in Central Asia than in tropical regions of the world.* This is because most Central Asian pasturelands cannot be used for crop production and are not the result of the conversion of more carbon-rich ecosystems such as forests.
3. *Livestock mobility is a function of herd size and vegetation condition in the area where livestock are based, and the distance to higher quality grazing elsewhere.* Following breakdown of migratory systems in the 1990s, an increasing number of livestock owners are once again travelling to remote pastures, but this re-expansion is dependent on the ability to cover costs of movement and investment in infrastructure. Those able to reach the economies of scale to move benefit from lower fodder costs and higher animal productivity whilst smaller owners remain on overgrazed village pasture, and are more dependent on fodder purchases. Use of winter pastures is particularly costly due to the investments in shelter that are required, but rewards can be significant.
4. *Collective herding systems facilitate use of remote pastures by smaller herders.* Traditional collective herding institutions have re-emerged, but land tenure systems, mostly based on individual land lease, make it difficult for these groups to obtain formal access to grazing. However, even within common property systems pasture access is a function of negotiation power, which negatively affects the ability of poorer and female livestock producers to realise their rights.
5. *Large areas of desert range are abandoned.* Many arid pastures of Kazakhstan and Uzbekistan are unused due to lack of water supply infrastructure and risks of crossing large desert tracts.
6. *Pasture degradation is spatially heterogeneous.* Grazing patterns suggest that pasture degradation is likely to be worst around villages and in proximate winter pastures and

there is plenty of evidence for this. Evidence that grazing has caused negative trends in vegetation productivity at larger scales is weaker.

7. *Institutional change is needed to improve pasture management.* The literature focusses on institutional measures and infrastructure improvements as ways of increasing mobility and use of remote pastures. Technical fixes such as reseeding and rotation are promoted by development projects but solid evidence of economic viability and real uptake is lacking.
8. *Conversion of crop to grazing land may promote environmental goals.* On marginal rainfed lands, relative to cropping, grazing is associated with improved ecosystem services, higher biodiversity and greater soil organic carbon over the long term. But these benefits may not always be internalised by individual users, leading to environmentally damaging land use practises
9. *There are synergies between improving access to pastures by smallholders and multiple SDG goals.* Improving access to remote pastures by smallholders may potentially improve productivity of their livestock, reduce inequality and address degradation on village pastures. It remains to be seen whether there are any trade-offs in terms of commercialisation of livestock production and investment in pastures by private individuals.

Research questions related to Topic 2

Research questions under Trade-off A. Commercialisation excludes smallholders.

1. *To what extent do smallholders benefit from improved legal access to pastures?* There is little empirical information on whether improving access of smallholders to pastures leads to uptake of the potential access rights (access to land being part of SDG targets 1.4 & 2.3), promoting farm growth, productivity, incomes and nutrition (targets 2.1, 2.2, 2.3, 8.2). In particular, it is unclear whether recent pasture reforms in Tajikistan, Uzbekistan and Kazakhstan have enabled greater pasture access and long distance movement by small producers, or led to measurable benefits for these users.
2. *Do common property systems promote or prevent value chain commercialisation?* Commercial operators argue that they need individualised access in order to develop and invest in pasture areas. There are no studies on the impacts of property rights regime on investments made by livestock producers in pastures and on whether investment models based on private individuals, the state or collective users are more sustainable or effective. This research area thus looks at trade-offs between the land access aspects of targets 1.4 and 2.3 and productivity growth aspects of targets 2.3 & 8.2.

Research questions under Trade-off C. More productive small livestock farmers degrade environmental resources.

3. *Does improved access to pastures by smallholders incur improvements in pasture management or does it conflict with environmental goals?* A priori, improvement of pasture access for smallholders through appropriate institutions and infrastructure investment should create synergies between land access aspects of SDG targets 1.4 & 2.3 and targets 15.3 & 15.5, especially on village pastures. But there is some evidence that economic factors may still keep small livestock owners from using remote pasture resources. It is also pos-

sible that better pasture access causes increases in livestock numbers, pressure on pastures and GHG emissions. In particular, there has been no research on whether recent pasture reforms in Tajikistan, Uzbekistan and Kazakhstan have stimulated improved pasture management and there are no studies which demonstrate environmental outcomes of different land management regimes. The economics and determinants of uptake of techniques such as seeding and rotation on pastures has not been investigated in detail, despite continued promotion by donors and governments.

4. *How significant is conversion of pastureland to rainfed cropland and what are the economic-environment trade-offs of this process?* This kind of land use change may improve food security (target 2.3), but incur trade-offs in soil erosion and carbon loss (and perhaps also longer-term economic losses in the livestock sector). There is little information on how important this process has been since the 1990s, nor on the implications for soil erosion, biodiversity and livestock production itself (targets 15.3, 15.5, 2.4 & 2.3).

Research questions under Trade-off E Economic growth compromises production resources in agriculture.

5. *What are the impacts of livestock commercialisation on feeding strategy and pasture use?* Commercialisation and value chain integration may lead to a drop in livestock mobility (a move to ranching-type grazing associated with investment in pasture improvements) combined with increased reliance on fodder. Alternatively, the pattern of increasing mobility with farm size recorded in Kazakh meat producing systems may be more common. Husbandry changes are likely to affect the environment through grazing, manure management and methane emissions (targets 15.3, 6.3 & 13.2), but the exact trade-offs associated with different production systems and drivers of intensification processes have been little researched.

Indicators

6. We have seen that different understandings of pasture condition, based on vegetation productivity or economic output, may not converge on the same perception of acceptable stocking rates. But there is little research comparing economic output from pastures per area and per head, at different level of vegetation productivity, which would enable the testing of this hypothesis. This question thus pertains to the measurements of indicators: 15.3.1 Proportion of land that is degraded over total land area; and 2.4.1 Proportion of agricultural area under productive and sustainable agriculture.

Topic 3. Intensification: fodder production and irrigation

A global perspective on intensification and SDG trade-offs in the livestock sector

Definitions of intensification

Livestock systems tend to transition from pastoral to mixed crop-livestock systems, and then from mixed crop-livestock to industrial systems, driven by human population growth, changes in consumption patterns and urbanization (Herrero et al. 2015). This process can create synergies between environmental SDGs on land degradation and climate, and economic goals through increases in efficiency, but is also associated with its own environmental costs which are quite different from those discussed in Topic 2. Intensification can lead to increased incomes amongst smallholders, but some face constraints which prevent them from reaping potential benefits. Elsewhere, the economic and climatic context may simply be unfavourable to intensification.

First however, we must define intensification, as this word has been used to cover a range of management and husbandry changes over the years. In crop production, the term has often been conceptualised as an increase in production per unit area of land, for example through shorter fallows (Boserup 1965), double cropping, yield increases, or a combination of all three (Babcock 2015). From a livestock perspective, definitions have included increases in production per animal and an increase in unit of animal source food (ASF) per unit of input such as labour, capital or land (Godde et al. 2018). Of these inputs, land is often chosen as the default factor in question, with increases in output of ASF (protein or calories) per unit of land used as a metric for comparison across systems or over time (Davis et al. 2015, Herrero et al. 2015). This '*land intensification*" may take place by improving grazing land using external inputs, increasing stocking rates on grasslands or through increased use of croplands for supplementary feeding. Another way of measuring intensification is by looking at total farm feed production intensity - the average amount of protein or calories in forage and fodder per total used land area - an index which is low on grazing land and high for cultivated feeds (Baltenweck et al. 2003). A fundamental concept when thinking about intensification is Feed Conversion Efficiency (FCE) – the efficiency by which an animal converts metabolizable energy (or protein) in feed to ASF. Because the roughage characterising extensive systems has a very low FCE, whilst conversion of feed used in intensive systems is highly efficient, this metric and land use efficiency are closely related.

Trends and drivers

Whichever definition or metric is used, global studies suggest increasing trends in livestock intensification (de Haan et al. 2010, Thornton 2010).The proportion of cropland used to feed livestock is one indicator of this, and grew from a very small area to around 33% today (Steinfeld et al. 2006, Thornton 2010). However, this statistic hides several conflicting processes. Firstly, although 35% of cereals (by weight) are currently used for feed, this proportion has actually decreased in recent years and growth in feed production has lagged behind that in livestock production since the late 1980s (FAO 2006).[7] This reflects a combination of improvements in

[7] Feed use for cereals grew at 2.4% in the 1970s (when livestock production was growing at around the same rate), but fell to 0.9% in the 1980s and 1990s, whilst production continued to grow at 2% per year (FAO 2006).

feed conversion efficiency in OECD countries and a shift of production to countries with lower grain-to-meat ratios; decreased use of cereals in countries like Kazakhstan – where transition disrupted feed availability; and decreases in subsidies for grain based feeds by the EU (FAO 2006, Steinfeld et al. 2006). At the same time, developing countries have been intensifying production, increasing grain provision to livestock. Their share of global use of cereals for feed doubled to 36% from the late 1980s to late 1990s (Delgado 2005 in Thornton (2010)) and this trend is expected to accelerate, driving new increases in the global share of cereals used as feed (Steinfeld et al. 2006).

Worldwide, the net outcome of these trends over the period from 1960 to 2010 has been an increase in livestock-sourced calories per unit of land of 165%, mostly due to increases in feed sources which compete for land with crops for human consumption, although systems using biomass unavailable for human consumption also saw increases in calorie production per unit area (Davis et al. 2015). However, efficiency gains are not equally distributed across ecological zones and land intensification in arid areas is least likely to be associated with increased feeding intensity and animal performance, and more to do with increases in stocking rates on rangelands (Godde et al. 2018). Today, mixed systems produce 69% of milk and 61% of meat (Herrero et al. 2015), with extensive grazing systems on rangelands accounting for only 7% of beef, 12% of sheep and 5% of milk; growth rates are much also higher on mixed systems and higher still in landless ones such as industrial pork and poultry production (de Haan et al. 2010).

Godde et al. (2018) break the drivers of intensification into a range of economic, technological and cultural and social factors, but population growth has been suggested as a fundamental underlying driver (Boserup 1965). As land becomes scarce and labour more available, labour will substitute for land, which will be worked more closely (for example by shortening fallows), often with decreasing returns for each unit of labour. As development proceeds and labour costs increase there is pressure to substitute labour for capital, so eventually productivity per land unit *and* per labour unit increase together (Baltenweck et al. 2003).

It has been suggested that the negative environmental consequences of intensification can be mitigated by increased incentives to adopt soil conserving innovations (Hayami and Ruttan 1985). Livestock-crop interactions are the major pathway to intensification, supporting sustainable mutually-reinforcing growth of both crops and livestock (Mcintire et al. 1992). However where populations grow very fast, rainfall is low and soils fragile or poor, or cropland lacking, pathways to intensification and marginal returns on increased inputs and labour may be low, or may not occur - and environmental impacts may be severe (Lele and Stone 1989). Commercialisation and specialisation may eventually lead to a de-coupling of crop and livestock farming, with attendant problems of soil fertility and pollution (Baltenweck et al. 2003).

Environmental trade-offs associated with intensification

The efficiency of intensive livestock production systems greatly mitigates their environmental impact. As we have seen above, the most common measure of this is feed conversion efficiency, which varies widely between different livestock products: conversion rates are 1% for ruminant meat, 7% for dairy and 10% for meat from monogastrics such as pigs and poultry (Herrero et al. 2015). This is largely due to low reproduction rates amongst ruminants. But these, often fed on grass and other roughage, have inherently lower feed conversion efficiency rates than monogastrics fed under industrial conditions. The shift to monogastrics therefore partly explains increases in global meat production efficiency (Thornton 2010). However, ruminant production is also becoming more efficient due to improved husbandry, genetics and feeding technologies (de Haan et al. 2010). From 1977 to 2007, FCE in the US beef production system is said to have increased by 19% (Crespi and Saitone 2019). Global FCE variation in beef systems (in kg DM feed per kg of beef carcass) ranges from less than 20 kg in Europe to over 100 kg in South Asia and sub-Saharan Africa, indicating potential for vast efficiency gains in many regions of the world (Herrero et al. 2015).

In order to take into account system efficiency, the environmental impact of different livestock systems is often compared per unit of ASF. In this way resource-use intensity (in terms of land, nitrogen and water) and output of pollutants (GHGs and nitrates from manure and fertilizer which pollute water sources) can be directly compared, supporting SDG trade-off analysis of livestock systems. But as we will see, FCE is not the only yardstick relevant to SDGs, as other concerns such as the insurance role of livestock, climatic conditions and the opportunity costs of different land use systems, must also be considered.

Intensification and resource-use efficiency

Land use efficiency: Davis et al. (2015) found that animal calories produced from crop production use on average 65% less land than those fed only on green fodder and natural grasslands. But this does not take into account the opportunity cost of using land for crops for human consumption. All livestock systems of whatever type are far less efficient at producing protein or energy per unit of land than plant based products grown directly for human consumption. However, grasslands and many types of marginal croplands cannot be used for crops for human consumption at all, so that such land, although producing little ASF per hectare, would produce zero human digestible food if used in other ways. Neither land quality nor opportunity cost is included in feed conversion efficiency measures or life cycle assessments of livestock production systems (Van Zanten et al. 2016). These authors thus propose a 'Land Use Ratio' which can support assessment of the relative suitability of production systems for livestock or human food crop production.[8] There is an argument that ruminants may be better for global food security than other livestock because they use mainly land or residues which cannot be used for other purposes. However, because many ruminant systems are mixed, globally they use as much cropland as pork and poultry per unit of product, with intensive beef systems the most wasteful in this respect (Herrero et al. 2015). It has been calculated that a shift in ruminant production to exclusive feeding on grasslands and food waste could provide a human population of 9 billion with about 20 g animal protein per person per day – lower than current Western consumption levels and below the anticipated global average of 31 g in 2050 (Garnett et al. 2017). In Central Asia, vast areas of underutilized rangeland cannot be used for human consumption, so that extensive systems in the region have very low LURs and high efficiency in terms of food supply. But trade-offs may include low FCEs, severe seasonal weight loss and high GHG emissions.

Water use efficiency: Livestock production uses two types of water: 'blue' water from rivers, reservoirs and aquifers used to irrigate crops and 'green' water from rainfall which is naturally available to rainfed crops and pastures. It has been argued that green water use has little impact on the environment as the rain would have fallen on vegetation and natural evapotranspiration

[8] The LUR is the ratio of human digestible protein (HDP) which can be produced from food crops on a given land type, to HDP from livestock products produced from grass, fodder or feed on that same land. LUR <1.0 is considered efficient in terms of global food supply and implies that animals produce more HDP per square metre than crops.

would occur whether crops and livestock were there or not (Herrero et al. 2015). Others suggest that green water availability can be affected by human activity through changes in the hydrological cycle resulting from deforestation and land degradation (Deutsch et al. 2010). Globally, the share of water used for feed production in irrigated areas is around 13% (Steinfeld et al. 2006), a figure expected to double in area by 2050 (Deutsch et al. 2010). In theory, ruminant systems may be highly water efficient where they use land unsuitable for crop production as only 'green' water is implicated in such systems. However, it has been estimated that at the global level ruminant meat supply relies on blue water resources to approximately the same extent as pork and poultry, per unit of output (Herrero et al. 2015). In Central Asia, intensification depends on fodder crop production, which in turn depends largely on irrigated land and thus on blue water, which is a scarce commodity. This suggests potentially high costs in water withdrawals and soil salinization.

Nitrogen use efficiency: Nitrogen use efficiency is an important environmental indicator where fertiliser is used, as this input requires energy for production and application, as well as being a direct source of GHGs. As is the case with sunlight, livestock systems waste more nitrogen than crop production, as much is excreted and only 5% (beef) to 40% (milk) of nitrogen intake finds its way into livestock products as protein (Smil 2002). But *within* livestock systems, intensification can be particularly wasteful where it involves chemical fertiliser application. The proportions of nitrogen fertiliser used to produce feed is around 20-25% globally (Steinfeld et al. 2006). Davis et al. (2015) found that the production of animal calories from feed sources which do not compete with human food crops was substantially more efficient in terms of fertilizer use—an average of 80% less nitrogen per animal calorie over the time period. This suggests that intensification implies trade-offs in nitrogen use efficiency, which also has implications for associated pollutants as we will present in the next section.[9]

Intensification and pollution

Intensive systems can benefit from links between animal and crop production, as manure is used to improve soil fertility, structure and water-holding capacity (Herrero et al. 2009). But under very high levels of intensification manure is no longer used as fertiliser or exceeds on-farm absorption capacity. Storage of excess manure, particularly in liquid form, is a significant source of GHGs (see below) - but the manure also finds its way into water courses and aquifers contributing to pollution, biological contamination and eutrophication (Menzi et al. 2010). In Europe, manure markets and strict regulations on application, storage and disposal mitigate negative impacts, but treatment costs can be very high (ibid.).

Overall, intensification processes are associated with the 13% of total annual livestock sector emissions from feed production and the 17% associated with manure storage (N_2O and CH_4) and fertiliser (N_2O). A further 16% from applied and deposited manure come from both grazing

[9] But Herrero et al. (2015), using the metric of *total* new fixed nitrogen (fertiliser application plus biological fixation) suggest that, whilst extensive systems generally use much less new fixed nitrogen per unit of land as they do not require fertiliser, they may use similar amounts of nitrogen per unit of *product* due to the very low FCE of these systems. On the other hand, GHGs aside, ruminant assimilation inefficiency has been said to be irrelevant if the animals are grass fed or raised only on crop residues – because these do not require external inputs of nitrogen (Smil 2002).

and mixed production systems (Gerber et al. 2013).[10] But the bulk of sector emissions is methane from enteric fermentation, which accounts for 40% of the total (ibid.). Because production of this gas is a function of feed digestibility, ruminant systems using higher quality feed produce far less methane per unit of ASF (Davis et al. 2015, Gerber et al. 2013). Reduction of GHG emissions has thus been advanced in recent years as a major argument for intensification of livestock systems (Topic 7).

Overall then, intensification can reduce GHG emissions and land use per unit of ASF. But such measures omit the opportunity and food security costs of using arable land for livestock feed. Intensive systems tend to be less efficient than grassland-based systems in terms of nitrogen and water use and cause direct pollution from manure. Many field studies have quantified and compared biological and economic trade-offs of different intensification pathways at the farm level (Paul et al. 2020, Takahashi et al. 2018, Tittonell 2013). But there are few examples from Central Asia. There are also broader social benefits to intensification which, through lower meat prices, has been linked to improved health and nutrition of the poor (Narrod et al. 2010) but here also, there is little written on the region of interest.

The fodder base in Central Asia: de-intensification and recovery?

Central Asia has seen a de-intensification of livestock production since the 1990s and the post-communist transition contributed to the above-mentioned drop in proportion of cereals fed to livestock (FAO 2006). Analyses of regional figures on changes in output of livestock product per hectare, or feeding intensity indicators such as those described above have yet to be conducted, but the reduction in animal productivity per head discussed in Topic 1 certainly suggests a decrease in feeding intensity. The fodder base of Central Asia is now overwhelmingly defined by a surplus of pasture forage in summer and a deficit of all types of forage, fodder and feed in the winter (Sedik 2010). The ability to overcome the winter feed bottleneck is perhaps the greatest challenge for sector development in the region.

In this section we look at the supply side in terms of fodder sources and availability, whether more recent changes may indicate a trend towards intensification and what the determinants of this might be at the farm level. In much of the region high quality feed can only be produced on irrigated lands, which make up 86% of all arable land outside Kazakhstan (Gintzburger et al. 2005). Like pastures, these systems have been subject to a series of institutional reforms and water management is one of the most pressing concerns in the region. We include a discussion of issues here as they are pertinent to the agricultural sector in general and are linked to a number of SDG goals.

Trends in areas planted to fodder

Following independence, the total arable area planted to fodder fell precipitously across the region, reaching a nadir in the 2000s (Figure 9). In the market-oriented republics, Kazakhstan and Kyrgyzstan, cash crops and crops for human consumption were quickly prioritised by producers, a tendency exacerbated by state plans in Turkmenistan and Uzbekistan. After 1992, the

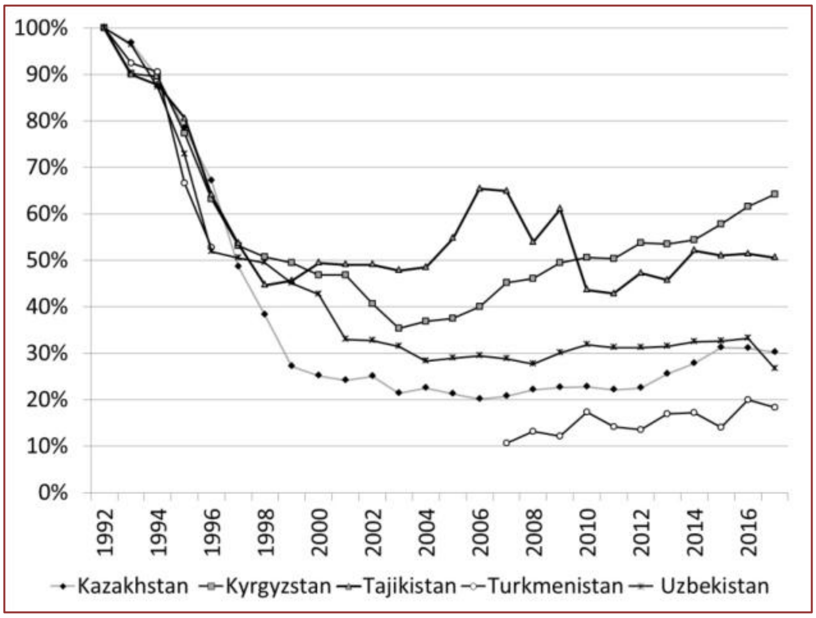
[10] It has been suggested that legumes used in grassland based systems may produce as much N_2O as fertilised non-leguminous crops as they fix N but emit N_2O (Steinfeld et al. 2006) - but this is a controversial topic as addition of legumes has complex and unpredictable effects on N and C recycling (Barneze et al. 2020).

total number of cattle in Uzbekistan increased 2.3 times whilst the area under fodder crops decreased by 73%, only partially compensated by yield increases (Naumov and Pugach 2019). Replacement of fodder by wheat in cotton rotations has caused deterioration in soil fertility (Zorya et al. 2019). The government plans to greatly increase the area under fodder but this will require important trade-offs given that the country has seen a reduction in sown area since 1991 (Naumov and Pugach 2019).

Tajikistan has lower numbers of livestock per hectare of fodder crop available than Uzbekistan and Turkmenistan (Table 2), but has much higher snowfall and longer winters. During the Soviet period stock were moved wholesale from mountainous regions to the lowland south of the country, but these migrations have all but ceased (Robinson et al. 2010b). In addition to loss of area sown, yields also decreased, and by 2007 cultivated fodder crops met only 37% of winter demand (Sedik 2010). The fodder crisis in Tajikistan is thus perhaps the worst of any country in Central Asia. Sedik (2010) estimated that even bringing yields to 1991 levels without increasing area could make a substantial difference, as would increase of fodder used in rotations with cotton.

A partial recovery. Since 2011 there has been a modest rise in areas planted to fodder in Kazakhstan and larger increase in total production (Djanibekov and Petrick 2020). Most of the increase is accounted for by individual farms which, along with enterprises, dominate fodder production on arable land (Table 2). Fodder crops are now designated as 'priority' crops eligible for area payments as part of Kazakhstan's efforts to diversify away from wheat (OECD 2020). In Kyrgyzstan, the area sown has grown strongly since 2003, increasing by over 20% from 2013 to 2017. In these two republics, fodder statistics include perennial and annual hays and maize, but exclude other cereals (which are discussed separately below). Maize accounts for 5% of fodder area planted in Kazakhstan, the majority planted by large enterprises (Kazakhstan Statistical Agency 2018).

Figure 9. Evolution in area planted to fodder crops – as % of 1992 figure



Adapted from Robinson (2020).
Sources: Kazakhstan Statistical Agency (2018); National Statistics Committee of the Kyrgyz Republic (2018) and downloadable data tables; Tajikistan: Djanibekov and Petrick (2020) & Statistical Agency of the Republic of Tajikistan (2018a); Uzbekistan: Djanibekov and Petrick (2020); Turkmenistan: Djanibekov and Petrick (2020) & State Committee of Statistics of Turkmenistan (2018); data missing for 1992-2006.

Table 2. Structure of fodder production in the five republics (2017)

Republic	% Arable land planted to fodder	Livestock units per ha of fodder planted	Area planted as proportion of 1992 figure	Percentage of total area planted to fodder crops, by farm type		
				HH	IF	E
Kazakhstan	15	3	31	0.5	53	47
Kyrgyzstan	31	7	64	5	92	3
Tajikistan	12	29	51	21	62	17
Turkmenistan	2	114	16	28	-	72
Uzbekistan	4	55	27	15	72	13

Adapted from Robinson (2020). HH=Household; IF=Individual Farm; E=Enterprise

Sources: Kazakhstan Statistical Agency (2018); National Statistics Committee of the Kyrgyz Republic (2018) and downloadable data tables; Tajikistan: Djanibekov and Petrick (2020) & Statistical Agency of the Republic of Tajikistan (2018a), Turkmenistan: Djanibekov and Petrick (2020) & State Committee of Statistics of Turkmenistan (2018). All figures are for 2017 except breakdown of area by farm type for Tajikistan (2016). For Turkmenistan much of the land under enterprises is leased to individuals and land planted by individual farms is aggregated with households.

In both Uzbekistan and Turkmenistan, areas planted to fodder crops are particularly small in relation to livestock numbers (Table 2), but in these countries desert pastures can be grazed in winter and much feed comes from waste agricultural products, such as cotton husks and seed cake. It is notable that Kyrgyzstan, in which livestock and land ownership are most closely aligned, has the highest proportion of arable land under fodder (Table 2). The deep structural reforms which occurred there may facilitate the ability of farmers to respond to market demand. In Uzbekistan, access to fodder by households may be higher than appears in statistics as this input is often part of payment received for services to farmers (IFAD 2015).

Natural hay, cut on pastures, meadows and along rivers is a crucial resource in all five countries, and is the main source of fodder for farmers lacking access to arable land or affordable fodder on the market. In some parts of the region, this type of hay is the *only* source of winter fodder. However, poor cutting and storage practises affect both natural and cultivated hay types, greatly reducing their nutritional value (Zhumanova and Maharjan 2012).

Use of cereals as livestock feed

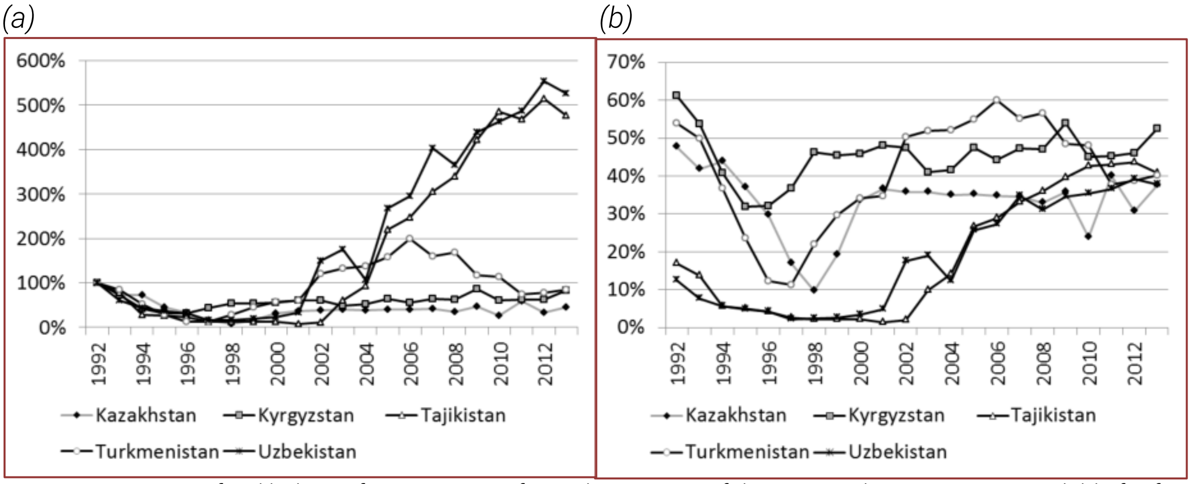
Much of the discussion in the introduction to this topic focussed on the use of concentrate feed grown on arable land for livestock. FAO food balance figures (Figure 10a) suggest strong increases in use of cereals for feed in Tajikistan and Uzbekistan from 2000 to 2013. Figure 10b suggests that these increases bring the proportion of grains used for feed (as percentage of total domestic supply) in those two countries up to levels of around 40%, closer to those of Kazakhstan and Kyrgyzstan.[11]

Although FAOSTAT figures for the use of cereals as feed include both domestically produced feed and imports, the patterns in Figure 10a tend to mirror those of domestic production. It has been noted that outside Kazakhstan, the quality of domestic wheat is so low that much is used

[11] Official statistics for Kazakhstan suggest that use of grains for feed as proportion of total grain utilised was 17% in 2013 (verses 38% in that year according to FAOSTAT). But from 2013, use of grain for feed increased year-on-year, both in absolute terms and as a percentage of total grain utilization, which reached 23% in 2017 (Kazakhstan Statistical Agency 2018).

as animal feed, while higher quality wheat is imported (Peyrouse 2013), but it is unclear how much of this feed is used for poultry production.

Figure 10. Use of grain as feed in Central Asia
*(a) Total available grain used as feed (as proportion of amount available in 1992)**
*(b) Grain used as feed as proportion of total available supply***



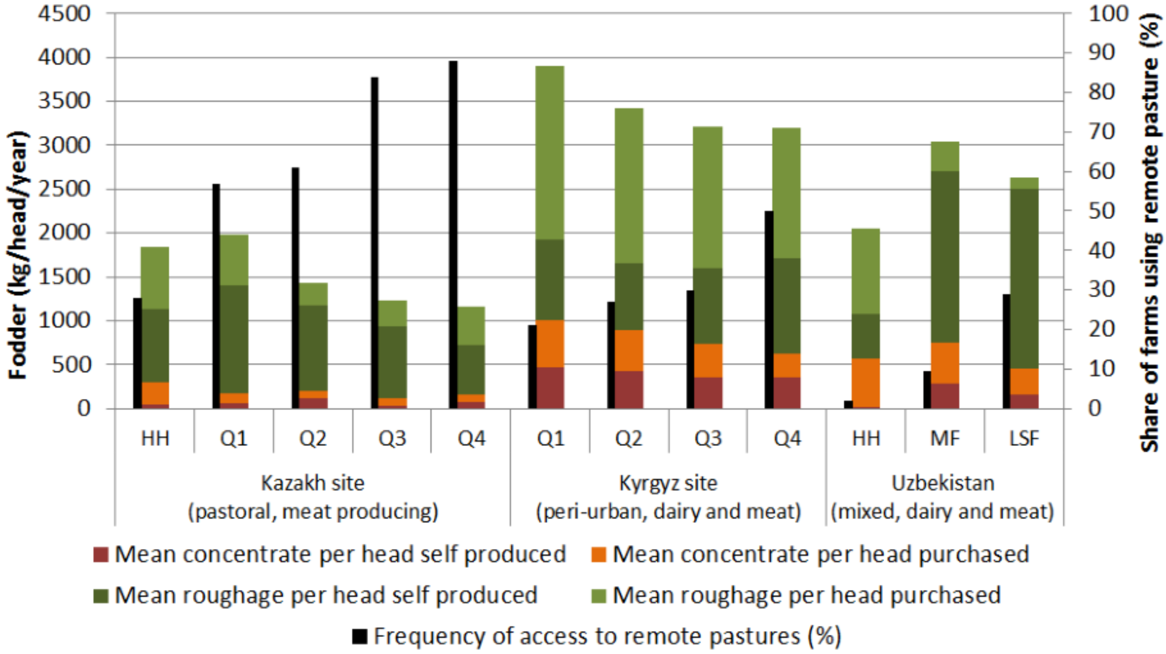
Sources: *FAOSTAT food balance figures. Data refer to the quantity of the commodity in question available for feeding to the livestock and poultry during the reference period, whether domestically produced or imported. ** Domestic supply quantity = domestic production + imports - exports + changes in stocks (decrease or increase).

Variability in winter feeding strategies – the determinants of intensification

Fodder availability and quality explain many features of low livestock productivity discussed under Topic 1, and aspects of farmer decision making in the livestock sector more broadly. However, within republics, feed composition and supply is not uniform but depends on distance from markets, whether the farm is focussing on dairy or beef production, and access to critical winter pastures.

For example in peri-urban areas, which are often close to high quality irrigated arable land and to dairy processors, fodder types are varied and may include combined feed, crop residues, high value cultivated hays such as lucerne and sainfoin, and silage (Robinson 2020). In remoter meat-producing areas, options for supplementary feeding are fewer. Here, destocking is often employed in the autumn and animals may be kept on a lower plane of nutrition over winter (Ur-Rahim et al. 2014). If high quality winter pastures are available, animals may be moved to these, reducing need for winter forage. Within sites, use of winter pastures reduces fodder requirements, but only larger herds can be moved due to the high fixed costs of occupying these areas, so there is a negative relationship between herd size and winter supplement provision. Data in Figure 11 demonstrate these different patterns from survey data, showing (i) variability in feeding patterns between sites having different access to pasture and markets and (ii) negative relationships between fodder provision per head and livestock ownership within sites. There are higher levels of feed diversity, quality and quantity at the Kyrgyz and Uzbek sites, which are close to markets, than at the meat-producing Kazakh site, which is further from markets, but endowed with large and diverse seasonal pastures. *Within* each site, increasing use of remote pasture with livestock ownership is clear.

Figure 11. Fodder composition and pasture use at three sites in Central Asia



Adapted from Robinson (2020).
Source: ANICANET survey data. Data at the three sites are split into different farm types as follows: Kazakhstan: household (HH) and individual farms by cattle ownership quartile (Q1-Q4); Kyrgyzstan: cattle ownership quartile (Q1-Q4); Uzbekistan (households (HH), mixed farms (MF) and livestock farms (LSF) in increasing order of livestock ownership – with mixed farms having higher access to arable land. Outliers over three times the inter-quartile range have been removed. In Kyrgyzstan, remaining high values are associated with large proportions of crop residue in the total ration. Some of these residues (listed under roughage), such as spent grain from beer production and various waste products from sugar-beet have a high water content, which may partially account for high values at that site.

The costs of fodder constrain sector development in many ways. It has been estimated that this input accounts for 70-80% of all costs for Uzbek dairy farmers (IFAD 2015) and 65-70% of the production cost of animal products in Kazakhstan (Ministry of Agriculture of Kazakhstan 2017). In the Kazakh beef sector feeding costs have been compared unfavourably with other countries (FAO Investment Centre 2010d). There are also many technical constraints associated with improved fodder production, and the economics of adoption of improved practices are little understood (Box 3). Bio-economic trade-offs associated with intensification have rarely been quantified in Central Asia, one exception being the study by Azarov et al. (2020) who conducted optimisation modelling for maximisation of gross farm margins and minimisation of pasture damage in high mountain pastoral systems of Naryn region (Kyrgyzstan). Optimal solutions were associated with reduction in stocking rates and expansion of improved fodder cultivation through higher quality seeds and more efficient cultivation techniques for perennial legumes, the major fodder source in the region.

Box 3. Technical issues of fodder production – seeds, mechanisation and storage

Leguminous fodder crops are a crucial source of high protein hay for Central Asian livestock and can be produced on marginal lands, unsuitable for many other fodder crops or cereals. They also fix nitrogen in the soil. Lucerne in particular was used in rotation with cotton during the Soviet period (Ibragimov et al. 2007) and a return to this practise has been suggested as a solution to problems both of fodder supply and soil degradation (Sedik 2010, Zorya et al. 2019). During the Soviet period high yielding lucerne cultivars were produced by the Uzbek Institute of Cotton Breeding and Seed Production (Ibragimov et al. 2007). But today seeds of perennial legumes are extremely expensive, it has been estimated that in Uzbekistan around 90% of fodder crop seeds are imported and there is a need to establish seed breeding and multiplication programs (Centre for Economic Development 2017).

Lucerne and sainfoin dominate green fodders by a large margin. They are both perennials and the cost of planting is recovered in the fact that the plants are grown for many years on the same piece of land - up to 20 years in some cases. This makes them problematic for short rotations. It has been remarked that use of annual legumes such as vetch (*Vicia* spp.) or grasspea (*Lathryus* spp.) is unusual in Central Asia (Thomson 2001). These can be grown under rainfed conditions provided rainfall exceeds 300 mm and produce grains rich in protein.

A second issue is storage. Hay quality is often extremely poor, affected by late cutting (causing protein content to drop considerably), high content of unpalatable grass species and rain damage before and after gathering (Thomson 2001). Time shortage for hay making and storing has been found to be at the root of many of these issues (Zhumanova and Maharjan 2012). Mowing, drying, transporting and storing must be conducted over a short period and require large amounts of labour. Increasing mechanisation of the fodder production chain, including the use of specialised machinery, has the potential to improve fodder quality substantially. However, lack of access by farmers to finance, suitable machinery and the relevant management know-how are all likely barriers to adoption. Better understanding of the binding constraints will require more research.

We have seen that natural hay cut on pastures or along rivers is an important source of fodder, but the quality is often very low. High-protein cultivated hays such as lucerne and sainfoin, root crops and grains are largely grown on irrigated land, which is a scarce resource in Central Asia, implying trade-offs in terms of food security and land-use opportunity costs discussed above. The challenges facing irrigated agriculture in Central Asia are thus important to consider in discussion on fodder crops and it is to these that we now turn.

Irrigated agriculture and fodder production

Like fodder area generally, that on irrigated land has greatly decreased (by around 60% from 1999 to 2009 (FAO 2013)).[12] But as we presented above, areas are rising again in some republics and there is evidence that an increasing proportion of cereal is being used for feed, much of which is likely to be irrigated (Table 3). Thus the water-use footprint of livestock production may be increasing, although an unknown amount may be for poultry and not the ruminant systems which are the focus of this report.

[12] This figure includes Afghanistan.

Efficiency and environmental costs of irrigation

Whilst the Soviets brought rainfed land under the plough in northern Kazakhstan, they greatly expanded irrigation systems in southern Central Asia. From 1965 to 1978 alone, the irrigated area in Turkmenistan and Uzbekistan grew by around 35% (Zonn et al. 1981). But water use increased at a faster rate than the area of irrigated land (Kolodin and Rabochev 1999); almost all irrigation in the region was by open furrow and the preferred crop was cotton, which has high water requirements. Yet the level of in-field drainage to remove excess water was low, leading to rising water tables, waterlogging, and accumulation of salt, which rises to the surface through capillary action driven by rapid evaporation at the surface.

Table 3. Irrigated lands in Central Asia

Republic	Irrigation status					Trends (later year as of earlier year)			% irrigated area planted to fodder & cereals		
	Year	Area equipped for irrigation as % cultivated area	% equipped area irrigated	% irrigated area equipped for drainage	% Area Salinized*	Year	% change in area equipped for irrigation	% change in water withdrawals for agriculture	Fodder	Hay, meadows	Cereal
Kaz	2010	9	61	17	17 (2018)	1993-2010	-41	-49	2.2	15.3	33.7
Kyr	2005	75	100	14	10 (2016)	1994-2005	-5	-22	10.7	10.5	50.3
Taj	2009	85	91	47	12 (2019)	1994-2009	3	-5	5.8	5.6	30.1
Turk	2006	102	100	58	96 (2012)	1994-2006	14	13	4.6	6.2	45.5
Uzb	2005	89	88	66	45 (2018)	1994-2005	-2	-7	10.8	2.7	35

Source: FAO (2013) except for *Mukhamedova and Petrick (2020).

Since the 1990s, infrastructure deteriorated further and many drainage systems, which in any case cover only a fraction of total irrigated area (Table 3), ceased to operate (FAO 2013, FAO/AGLL 2003). Statistics suggest the loss of around 980,000 ha in area equipped for full control irrigation, most of which occurred in Kazakhstan, and a reduction of water withdrawals in several republics (Table 3). Of land equipped for irrigation, the area actually used fell by around 10% in Uzbekistan and Tajikistan (FAO 2013).

Water losses are enormous due to unlined or leaky canals, a lack of working water metres, and cropping patterns which do not promote water use efficiency. In Tajikistan, some irrigation depends on pumping groundwater, and although many pumps fell into disrepair, agriculture consumes 10% of Tajikistan's annual energy supply (Shenhav et al. 2019). Recent studies have shown that a large proportion of farmers in Uzbekistan suffer from water shortages, with those furthest from the beginning of main canals having both lowest productivity and agricultural incomes (Bekchanov et al. 2010a).

There should therefore be very strong incentives for water saving. Concerning technical solutions, uptake of capital intensive water saving technologies such as drip irrigation or laser levelling has been found to be unlikely in Uzbekistan due to high costs, although increased market commodity prices, liberalization of farming and a more even distribution of water could improve the economics (Bekchanov et al. 2010b). For the moment, cheaper measures such as double flow, short and alternate dry furrow techniques have the highest potential to be adopted (ibid.).

But just as important as technical solutions, are economic incentives for water saving, which involves passing costs to farmers. This price signalling is undermined both by the cost of installing meters and cultural barriers to optimization of water use (Oberkircher and Hornidge 2011). Underlying all these issues are dysfunctional institutional mechanisms for water management (Bekchanov et al. 2010b), and it is to these that we devote the next section.

Institutional challenges of water management

Soviet-era authorities provided water to state/collective farm head gates by district offices of government water resources departments, whilst on-farm irrigation infrastructure was operated and maintained by the farms themselves. Decollectivisation meant the loss of the brigades which previously managed water provision, so new institutions for on-farm irrigation services had to be found. Initially, district irrigation departments took over water provision, but had severe difficulties adapting from suppling a handful of state farms to servicing the many thousands of new farms resulting from reform. In Kyrgyzstan the government introduced a fixed irrigation service fee in 1995, but this could not make up for loss of Soviet-era state funding and by 1996 the available budget was only 25% that of 1990 (Akramov and Omuraliev 2009, Johnson III and Stoutjesdijk 2008). Most republics, faced with similar problems, began to experiment with Water Users Associations (WUA), an idea promoted by international donors and based on the principles of Integrated Water Resource Management. These include the management of water at the level of natural catchment areas, participation of users, and treatment of the resource as an economic good (Amirova et al. 2019).

In most cases, the organizational set-up of a WUA is that of a non-governmental structure that operates to the benefit of its members, the water users. WUAs are supposed to control and account for water use by members; organise water offtake, distribution and drainage; approve norms, plan and limits for water use; and undertake maintenance of irrigation systems. Advantages are said to be more efficient and adaptable service provision, improved water use efficiency; and reduction of the financial burden on government (Djalalov 2006). Such forms of 'transfer of irrigation management' to users are said to have been successful in other parts of the world, notably Southeast Asia (MacDonald 2019), and today 57 countries (covering 76% of the world's irrigated area) have invested in this approach to various extents (Garces-Restrepo et al. 2007).

But strong path-dependency on water institutions established during the Soviet Union has undermined the new water governance norms. WUAs were generally established in a top down manner according to single templates. Institutional arrangements dividing water users into members and non-members based on their legal farm status excluded many de facto water users whilst vested interests of high and mid-level authorities have prevented small commercial farmers and households from owning and managing these institutions (Mukhamedova 2019).

Even where institutional and legal frameworks are sound, WUA development has been hampered by lack of funds for operation, absence of qualified staff, government interference, lack of real member participation, and by the fact that physical irrigation systems were designed to serve big farms (Kazbekov et al. 2007). In some cases reforms were conducted only on paper in order to receive financial resources from donors, with membership participation limited to the initial establishment meeting (Theesfeld 2019). Many WUAs in Central Asia have poor fee collection rates, are unable to fully maintain the irrigation and drainage network and do not provide efficient, timely or equitable water provision (Abdullaev et al. 2010). But there are also success stories and examples of functioning organisations from which to learn. Box 4 describes individual country experience.

Box 4. Country experience with WUAs

In Uzbekistan WUAs, first introduced in 1999, reached almost complete coverage by 2008 (Mukhamedova and Wegerich 2017). However, dekhan farms (households) cannot be individual members of WUAs either as household plot owners or as tenant farmers (Djalalov 2006). Case studies in the Ferghana area, where efforts have been made to integrate households, show that even here these are represented as users only through settlements – so that a settlement with thousands of kitchen gardens is counted as a single user - on a par with a single individual farmer (Mukhamedova and Wegerich 2014). Such household users are poorly represented in WUAs and often resort to informal means to obtain water, refusing to pay fees, breaking WUA rules and even water management infrastructure (Mukhamedova and Wegerich 2014, 2017). The irrigated area under households plots expanded from 5% to 17% of the total from 1980 to 2010, and production intensity (and thus water demand) on them is growing, thus these issues need to be resolved to avoid outright conflicts between villages and farmers (Mukhamedova and Wegerich 2017). A second issue in Uzbekistan is the re-interpretation of WUAs as state organs. Leaders are appointed, not elected by members, and are accountable to state organizations rather than to members (Veldwisch and Mollinga 2013). Before WUA establishment, farmers paid symbolic amounts for water, so following introduction of water fees, non-payment to WUAs was rife. The state may oblige WUAs to provide water to farmers working on state quotas, regardless of whether fee payments have been made, undermining financial sustainability (Djumaboev et al. 2017). Payments are often made per hectare rather than by water volume, thus there are few incentives for water saving.

In Kazakhstan, work by Zinzani (2015) suggests that the legal basis for WUAs is stronger than that in Uzbekistan, and that they are independently established by water users. Some WUAs perform relatively well, but they are often run by former state farm staff previously responsible for water provision, with little participation by members. Some WUAs have gone bankrupt, reducing enthusiasm for establishment of new ones. Ten years after the law establishing WUAs was issued, most of the irrigated lands in the three districts of South-Kazakhstan province studied were still under the responsibility of district water department (Zinzani 2015).

By 2015, around 400 WUAs covered almost 400,000ha of Tajikistan's cropland land, mostly established through donor projects. But legislation is weak; there is poor coordination between local water authorities and WUAs (with double fees charged in some cases), lack of proportionality between tariff rates and consumption; little penalisation for non-payment; and unclear demarcation of WUA territory (Shenhav et al. 2019). There is no legal clarity regarding whether households have the right to WUA membership and in practise they are usually excluded as their kitchen gardens (and thus water use fees) are small (MacDonald 2019).

In Kyrgyzstan, establishment of WUAs was accompanied by large donor investments in capacity building. This training role was later absorbed into the department for water resources and district irrigation departments now have a supplier-client relationship with WUAs (Johnson III and Stoutjesdijk 2008). These authors report very high irrigation service fee collection rates. However others report difficulties with fee collection and elite capture of water resources (Akramov and Omuraliev 2009). Kazbekov et al. (2007) present a more heterogeneous picture, using standardised metrics for empirical assessment including water productivity (the amount of water used per unit of agricultural output); delivery plan ratio (ratios of actual and planned deliveries); equity of water delivery; financial self sufficiency and fee recovery ratio. The authors found fair performance in some cases, but also detected issues with oversupply and high levels of inequity between canal outlets. Coverage of expenditures was between 50% and 70% and fee collection between 55% and 68%, resulting in some cases in suspension of water provision by the state authorities. These results were obtained in the republic with perhaps the best environment for WUA establishment, and in areas which had been well supported by donor projects.

Gender and irrigation

The above issues, in particular exclusion of households or elite capture of water supply have important implications for SDGs 6.4 (on water use efficiency) and 2.3 (on food security and access to resources for production by smallholders). But gender dimensions (SDG 10.2) are also highly significant. In Uzbekistan, kitchen gardens are often managed and watered by women, whilst election of water masters and decision-making on water allocation within the WUA is male dominated (Mukhamedova and Wegerich 2014). This compounds the poor negotiating position of households regarding water access and the informal arrangements which households must use to access water outside WUAs are often practised by women in particular (Mukhamedova and Wegerich 2014, 2017). In Tajikistan, labour migration means that many individual farms are now operated by women, but departing men are less likely to pass technical information about water management to women, who are also less likely to participate in WUAs (Balasubramanya 2019). On the other hand, Mukhamedova and Wegerich (2018) provide evidence that, in this republic, greater participation in farming (as farmers but also as workers) has meant that women have taken over agricultural service provision, including water administration, facilitating engagement with women farmers and thus contributing to a “feminisation” of agriculture.

The problems with WUAs mentioned here are not unique to Central Asia (Garces-Restrepo et al. 2007). There is nothing intrinsic to Central Asian societies which precludes cooperation in water management; experimental studies have shown that when there is sufficient communication between users, policies entrusting them with management autonomy are likely to work well (Amirova et al. 2019). The region has strong traditions of water management manifested in the institution of *mirab* or water master, responsible for water allocation, and there are reports that users have been reorganising spontaneously at the tertiary canal level, which is below that of the collective farm and current WUA (Abdullaev et al. 2010, Kazbekov et al. 2007, Mukhamedova and Wegerich 2014). Changes to the legal and institutional position of households in water supply systems, financial support, capacity building and political support for enforcement of WUA authority and rules would all support improvement. Training and capacity development in particular have been shown to be very effective in improving participation and fee payments (Balasubramanya 2019, Johnson III and Stoutjesdijk 2008).

Major insights under Topic 3

1. *Intensification is often defined as the increased production of livestock products per unit of land, through provision of higher quality forage or feed and improved breeds.* This can be can be achieved by grassland improvement, use of cultivated legumes, crop residues and grains. Intensification results in higher feed use efficiency, reducing GHG emission intensity and using less land per unit of ASF. But intensification can incur opportunity and food security costs where arable land is used for feed. Intensive systems are less

efficient than grassland-based systems in terms of nitrogen and water use and can cause direct pollution from manure.

2. *Across Central Asia, since 1990 competition with food and cash crops has driven down land use by fodder crops. Government food security targets often advocated or even mandated this process.* Some recovery has been seen in Kyrgyzstan, which has the lowest disparity between livestock ownership and land access, and where farmers have greatest land tenure security and freedom of decision making. In some republics there is evidence that the proportion of cereals grown for animal feed is increasing. Regionally, the overall share of arable land and water dedicated to livestock production is probably rising - but data are insufficient to judge the magnitude of this trend.
3. *Quality and quantity of fodder provision depend on proximity to markets and availability of arable land, winter pastures and herd size.* Within republics, farmers near markets and specialising in dairy are most likely to invest in improved fodder provision. In remoter meat-producing areas, farmers provide less and lower quality fodder. However, where snow free winter pastures are available, it may be more profitable to send large herds to these areas than to provide supplements.
4. *Deficiencies in water management and severe soil degradation hamper the contribution made by irrigated areas to fodder production.* In many regions the only fodder provided to animals is natural hay, often of poor quality. Provision of improved hay or concentrate often depends on irrigation but irrigated lands in Central Asia suffer from poor management and environmental problems such as salinization. User-based water management institutions exclude households in at least two republics. Improvement of these would have synergetic outcomes for multiple SDGs including 6 (water use efficiency), 10 (reduction in inequality), 2 (zero hunger), 1 (no poverty) and 15 (life on land).
5. *Improved cultivated hays can support both the livestock sector and soil fertility.* Greater inclusion of legumes in rotations requires long term planning and is likely to depend on greater farmer independence and tenure security in countries like Uzbekistan. Moreover, seed availability and cost may be significant barriers to adoption. Synergies here include improved livestock and crop productivity and a lower carbon footprint (Topic 7).

Research questions related to Topic 3

Research questions under Trade-off A. Commercialisation excludes smallholders.

1. *What are the extent and determinants of water supply inequality in each republic and are there economic trade-offs involved in improving irrigation water supply to households?* We have seen that in Uzbekistan and Tajikistan households have the poorest access to water (affecting targets 10.1, 10.2, 2.3 & 1.4), but little is known about this issue in other republics. Understanding the circumstances under which 'elite capture' of water occurs in other republics, and whether trade-offs for commercial farming (target 8.2) could result from improving water supply to households could be the subject of further research.
2. *To what extent do households and small farms obtain fodder through arrangements with larger farms and enterprises?* Smallholders and households are highly reliant on winter supplements; can formal or informal contracts with larger farms or alternative

market arrangements solve the fodder deficit for these producers, creating synergies between SDGs 2.3 and 8.4?

3. *How does the commercialisation of beef and milk production affect feeding strategies and food security?* Under what conditions do commercialisation and value chain integration (target 8.4) lead to increased use of feed and fodder crops and what will be the trade-offs for food security (targets 2.3 & 2.4) if scarce irrigated land is converted to these uses?

Research questions under Trade-off B. *Rising incomes lead to malnutrition and ill-health.*

4. *Are there links between intensification, lower ASF prices, and improved (or deteriorating) human health and nutrition?* In some parts of the world intensification has led to improved health indicators amongst the poor, but lower prices may also lead to overnutrition (both are indicators under SDG target 2,2). Such links between intensification, livestock product prices and health have not been explored in Central Asia.

Research questions under Trade-off C. More productive small livestock farmers degrade environmental resources.

5. *What pathways to intensification are being used by farmers in Central Asia and what are the bio-economic trade-offs involved?* Given the scarcity of arable land and water in the region, farmers find different ways of improving feeding intensity of their animals. These more intensive feeding strategies will have varying impacts on pasture use and quality, agricultural soils and water availability. Trade-off analysis using comparisons of farm profitability, animal productivity, and environmental footprints along axes of intensification have been conducted in many countries, but rarely in Central Asia. This question thus examines the nexus of food security and agricultural productivity (targets 2.3 & 2.4), water scarcity and pollution (6.3 & 6.4) and climate, biodiversity and degradation indicators affected by pasture use and management (13.2 & 15.3).
6. *Are improvements in water use efficiency compatible with improved access and more equitable water supply?* Related to question 1, is how access to water can be improved without exacerbating water scarcity (target 6.4) and soil salinization (target 15.3). This research question addresses the kinds of institutions are likely to facilitate efficient water management whilst supplying water to all (aspects of targets 2.3 & 1.4 on access to productive resources), and how better water provision to smallholders can be reconciled with adoption of water saving technologies, which in turn may be capital intensive (target 8.2 on economic growth through innovation and investment).
7. *Can synergies between fodder crop production, soil improvement and yields of other crops be realised?* What are the costs, benefits and obstacles to increasing the use of leguminous fodder crops in rotations under different land tenure scenarios? Whilst greater use of rotation may improve soils and provide fodder for livestock, there may be economic trade-offs in the short term which prevent this practise from being implemented (nexus of targets 2.3, 2.4 & 15.3).

Research questions under Trade-off E Economic growth compromises production resources in agriculture.

8. *How does the commercialisation of beef and milk production affect feeding strategies, crop choices and water use?* Related to 3 and 5 above - will increasing commercialisation and value chain integration lead to increased reliance on feed and fodder crops, greater use of extensive pastures, or even compete with food production by introducing grain or maize into fodder rations? What will be the trade-offs for pasture, water use and soils? In particular, examination of the costs of fodder provision verses winter pasture use has been little addressed outside Kazakhstan. This question thus exam-

ines the nexus of food security and agricultural productivity (targets 2.3 & 2.4), economic growth (8.2), water scarcity and pollution (6.3 & 6.4), and climate, land degradation and biodiversity (13.2, 15.3 & 15.5.).

Indicators

9. *Data on irrigation water supply.* Data on metrics of water supply such as water productivity, delivery plan ratio and equity of delivery are important for the above research questions, and for measuring progress to SDG target 6.4 in particular. The extent to which these indicators are measured by WUAs, or whether they are reliable, is a research topic in itself.

Topic 4. Livestock species, genetic improvement and animal health

Breed improvement, SDG attainment and trade-off analysis

Improved livestock performance supports the attainment of SDGs 1 (no poverty) and 2 (no hunger), as well as supporting overall sector growth (SDG 8). Improved genetics has made an important contribution to both global livestock production and to the efficiency gains discussed under Topic 3. The replacement of a large number of poor yielding animals by fewer but more productive and better fed livestock would greatly reduce total GHG emissions from the livestock sector (Herrero et al. 2009). Gains have been achieved through breed substitution, cross breeding and within-breed selection. Increased specialisation and the associated selection for specific traits such as milk yield has been supported by technologies such as artificial insemination (AI) and new genetic and statistical techniques which improve the predictive accuracy of animal selection for breeding (Thornton 2010).

But selection for narrow sets of characteristics and promotion of extremely high yielding but specialised breeds can have trade-offs with other traits such as adaptability to seasonal weight loss (essential in Central Asian systems), disease resistance and adaptability to certain climatic conditions (Lamy et al. 2012). Narrowing of the genetic resource base in developed countries demonstrates the need for conservation as insurance against climate change and new disease threats, as stated in SDG target 2.5 on the maintenance of genetic diversity of seeds, cultivated plants and domesticated animals. One example of loss of genetic diversity is the reduction in milk production share in the USA from a diverse range of breeds in 1945, to production of 90% of milk by Holstein cattle, whose intra-breed genetic diversity has also fallen sharply over time (FAO 2018a).

High yielding breeds also demand investments in feeding and other husbandry costs. Whilst these breeds uncontestably produce the highest yields per animal under the right conditions, in developing counties they do not always lead to the highest profits per farm. The specialisation entailed also involves a range of trade-offs which may constitute obstacles to adoption of new breeds (see Box 5 for examples from the literature).

Box 5. Trade-offs associated with improved breeds

Salmon et al. (2018) describe a study from Senegal which compared small dairy farms holding a range of breeds from locally adapted pure Zebu through crosses to pure introduced *Bos taurus* cattle. The study compared milk yields per animal across these farms, which varied according to genetic potential and feeding level; but it also looked at profits and cost-benefit ratios, to identify the economically optimal combination of breed and feeding regime, which turned out to be associated with a medium-yielding species of cross-bred cattle. The authors also compared greenhouse gas emissions enabling deeper understanding of bio-economic trade-offs.

Paul et al. (2020) examined dairy systems amongst Tanzanian smallholders, looking to identify viable sustainable intensification options. The authors found that systems with improved breeds had greatest potential to produce low GHG intensities whilst maintaining high farm N and C balances and with relatively small trade-offs with other farm performance dimensions such as income. But a successful shift to such systems requires a range of husbandry and veterinary conditions as well as high labour demands. Lack of knowledge, a reduction in multi-functionality of livestock for draught power and savings, and increased risk associated with the specialised breed (higher mortality, low fertility, adaptability to local climate and diseases) were all obstacles to adoption.

Livestock, wildlife and human health are tightly linked (One Health Initiative Task Force 2008). The majority of new infectious diseases reported since the 1940s can be traced to animals and zoonoses (which cause 2.7 million deaths per year) hamper attainment of SDG 3 – healthy lives (FAO 2018a). Through disease, food safety and output, animal health also affects farm incomes, investments, access to value chains and economic growth (Topic 5). It has implications for target 15.5 (on biodiversity) as disease spill-overs from livestock to wildlife have resulted in high levels of mortality in some species in recent years. Trade-offs here occur between the benefits of keeping livestock and these risks, in situations where veterinary services are poor or patchy.

In this section we ask whether there is any evidence in Central Asian livestock systems for trade-offs between yield gains of high performing breeds, farm incomes and loss of local genetic diversity. We look at the state of animal health in the region and summarise current knowledge on the impacts of livestock disease on human health and the economic potential of the sector.

Livestock breeds in Central Asia: trends and trade-offs

Breeding in the Soviet period

Central Asia is home to a number of indigenous livestock breeds such as fat-tailed sheep, cashmere goats, yaks and Bactrian camels, adapted to an extreme continental climate and large fluctuations in feed availability (FAO 2007, Lamy et al. 2012). The Soviets imported Merino sheep for fine wool production to the detriment of the local fat tailed variety, and the local cashmere producing goats were crossed with Angora goats to produce a new breed having increased volume of down, but lower fibre quality (Kerven et al. 2002). The indigenous Karakul sheep breed was highly valued and Uzbekistan and Turkmenistan produced pelts on specialised farms, for sale within the Soviet Union (ibid.).

Cattle (*Bos taurus*) numbers greatly increased with the Russian colonisation of Central Asia and during the Soviet period, a number of local cattle breeds were developed. The dual purpose Ala-Tau was a cross of Swiss brown and local breeds developed in Kazakhstan and Kyrgyzstan, achieving annual milk yields ranging from 4,500 to 5,488 kg with almost 4% fat content and high daily weight gains in steers (Dimitriev and Ernst 1989). Suitable to harsh unpredictable climate and terrain, the Aulie-Ata dairy breed likewise arose from crossing local Kazakh cattle with the Dutch black pied dairy breed, upgraded with Friesian and Holstein imports. Average milk yields reached 3,735 kg, with fat content of 4% but some herds produce up to 5,000 kg per year (Dimitriev and Ernst 1989, FAO Investment Centre 2010a). Bulls and semen from Europe and America were regularly imported and artificial insemination combined with improved winter feed, enabled a gradual "Holsteinization" of the Kazakhstan dairy cattle population (FAO 2011a). The Kazakh white head was a local – Hereford cross created to establish a basis for the beef industry, combining tolerance of heat and cold, with rapid weight gain, bulls weighing around 420 kg at 15 months (Dimitriev and Ernst 1989, Nurgazy et al. 2019).

Central Asian zebus and zeboid cattle (*Bos taurus indicus*) were raised in Uzbekistan, Tajikistan, and Turkmenistan. The zeboid is a nearly humpless animal originating in crosses between local cattle and the Iranian zebu as early as the 7th or 8th century A.D. (Dimitriev and Ernst 1989). Ergashev et al. (2007) list characteristics of the Tajik zebu as including: high-fat milk, excellent meat, high resistance to tick-borne theileriosis and high fertility with synchronized calving seasons. The breed is small, with very low milk yields but performance is highly resistant to poor feeding and they survive well in Tajikistan's rocky mountainous areas. Dimitriev and Ernst (1989) describe experimental crosses with beef breeds to increase live weight and hasten maturity, and with Swiss browns to raise milk yield.

Breeding since 1991

Breeding programmes collapsed in the 1990s and the mixing of private and former state animals led to loss of breed purity, combined in some cases by active abandonment of breeds like Merino sheep in favour of local fat tailed sheep and small cattle. Hardiness and fertility were favoured over productivity (Zhumanova and Maharjan 2012). The proportion of goats in comparison to sheep rose enormously in the 1990s and 2000s, being preferred by poorer mountain farm families as more productive than sheep and easier to raise (Kerven et al. 2011).

Changing markets also influenced these decisions. Local goats produce cashmere, which is an increasingly commercialised commodity (Waldron et al. 2014). Meat prices rose whilst global fine wool prices collapsed in the 1990s and 2000s, hastening the switch from Merino sheep to fat tail breeds amongst which Hissar animals are particularly prized (Kerven et al. 2011). By the middle of the 2000s, international demand for fine wool bounced back (World Bank 2007) and Kazakhstan now exports fine and semi-fine wool to China and Russia (FAO Investment Centre 2010c). This has prompted renewed interest in breeds such as Merino and Kyrgyz fine wool sheep, for which state breeding farms continue to function (Tilekeyev et al. 2016). In contrast, a number of Kyrgyz meat and semi-fine wool breeds are on the brink of extinction (ibid.). In Tajikistan, Ergashev et al. (2007) report that pure bred local zebu and zeboid cattle have also declined.

Recently, attention has returned to the enhancement of beef and dairy breed performance through import of breeds from abroad and large dairy farms in Kazakhstan now function largely with imported Holstein semen and cattle (FAO 2011a). At the same time, it has been suggested that insufficient attention is being given to the potential of local breeds, some of which are dwindling, at least on large farms in Kazakhstan (FAO Investment Centre 2010a). The Kazakh *Sybagha* programme[13], which subsidises the purchase of pedigree bulls, had a high uptake rate amongst large farmers and Kazakh or regional breeds are still popular amongst some of these, as well as medium-sized farmers.[14] Overall, around 11% of cattle and 15% of sheep in Kazakhstan are said to be pure breeds (Ministry of Agriculture of Kazakhstan 2017). Numbers of pedigree meat cattle have doubled since 2012 – mostly of Kazakh White Head, Auleikol, Angus and Hereford (Ministry of Agriculture of the Republic of Kazakhstan 2018). But according to survey data the vast majority of cattle owners do not have access to a pedigree bull of any type.

In Uzbekistan, nearly 52,000 head of pedigree cattle have been imported in recent years and in 2016, breeding farms produced more than 7,700 heads of cattle, which were sold to farms and

[13] Full statistics on this programme are available on http://sybaga.kz/Home/Index

[14] Some of the findings in this section based on unpublished ANICANET survey data, see www.iamo.de/anicanet for details.

households (Al Mar Consulting 2017). But as in other republics, data on uptake and subsequent performance are difficult to find. Kyrgyzstan's current agricultural support programme (Agricultural Financing 2018-2020)[15] includes subsidised loans for agriculture, a specific proportion of which must be for livestock breeding. The breeds specified in the programme include a wide range of local and foreign breeds such as, for cattle: Alatau, Cherno-Piostre, Aulie-Ata, Holstein, Jersey, Simmental, Ayrshire, Hereford, Dutch, Yaroslavl, Kholmogorsk; and for sheep: Tien Shan semi-fine-wool, Alai and Merino. Horses and yaks are also included in the programme.

The above information suggests that despite imports of high yielding Western breeds, local breeds and crosses are also being promoted and are included in national breeding and subsidy programmes. But the overall status and threats to local genetic diversity is unknown. According to Global Databank for Farm Animal Genetic Resources (FAO 2007) only 4% of regional livestock breeds are categorized as at risk. However, this is probably an underestimate of the actual situation. Population data are available for only about half of breeds, and those most at risk are likely to be those for which information is lacking (ibid.). In all republics, the major problem with breeding programs is the lack of control of mating once the bull reaches the farm, as animals from different herds mix, especially on summer pastures. For this reason, a suggested breeding support strategy for small farms would be to hire pedigree bulls to graze with cow herds, and to castrate all other bulls (FAO 2011b).

Impact of breed adoption in Central Asia

Given that SDGs on food security, poverty reduction and economic growth are all lifted by higher rural incomes, farm profitability is a key indicator by which the performance of cattle breeds should be judged. But there is little information about the economic impact of breeding programmes at the farm level, although it has been noted that imported high performing breeds are often raised without the requisite improvements in feeding and husbandry regimes. IFAD (2015) note that commercial farmers in Uzbekistan invest into pedigree cattle such a Holstein and Simmental, but still run their business with simple cow-sheds, poor milking parlours and sub-optimal fodder storage. FAO Investment Centre (2010d) suggest that, as local breeds rarely reach their full potential, it would be better to close this gap through better feeding rather than to distribute semen of cattle such as the Holstein, whose potential would be even less attainable under local conditions. Moreover, most cattle are kept for producing both milk and beef, so that dual-purpose breeds are likely to be more appropriate (FAO 2011a).

We were unable to identify literature of the type presented in Box 5 - directly comparing economic benefits and environmental costs across farms of using different breeds of livestock and associated management systems. Central Asian scientific literature tends to emphasise animal performance and mention neither feeding rations nor costs of production (Kazhgaliyev et al. 2016, Nurgazy et al. 2019). But comparisons of the profitability of different types of dairy farm suggest that production costs per litre of milk of very large farms using imported Holsteins are higher than those of small producers and these modern dairy farms are viable only due to subsidies for imported animals, loan interest rates, milk prices and AI services (FAO 2011a). Survey data cited above suggested that in Kazakhstan, farm size is a major determinant of the uptake of breeding programmes; it is likely that production priorities and risk aversion may also be important (Gerber 2004) but these have not been investigated in the region.

[15] For further details see http://cbd.minjust.gov.kg/act/view/ru-ru/12103.

Animal health in Central Asia

The biothreat situation in Central Asia has been called 'the most significant existing impediment to realising the full market potential of the region's animal products" (Walker and Blackburn 2015). In Kyrgyzstan the poor animal health situation and lack of effective veterinary services have been identified as the main constraint to livestock sector development (IFAD 2016, World Bank 2007) and the most significant variable constraining expansion by large-herd owners (Zhumanova et al. 2016). Swinnen et al. (2011) note that lack of food safety, and in particular lack of testing facilities, affect investment in value chains and prospects for export. In Kazakhstan disease poses a moderate risk to the sector as surveillance and control are improving (Broka et al. 2016b).

Zoonotic diseases

Zoonoses (animal diseases which may also infect humans) have implications for food safety and human health and it has been estimated that around 60% of pathogens causing human disease are of animal origin (Salmon et al. 2020). In Central Asia diseases of highest risk include brucellosis, bovine tuberculosis and echinococcosis (Broka et al. 2016a, 2016b, Torgerson 2013). Rabies and anthrax are reported sporadically; but are subject to control through vaccination of livestock in all republics.

With half a million new cases reported globally every year, brucellosis is one of the most economically important zoonoses, ranked seventh in terms of its impact on human and livestock health and amenability to interventions (Grace et al. 2012). Like many other endemic diseases it is underreported and is classed as a research priority by the World Health Organisation (WHO 2012). In humans, it is a chronic debilitating disease which is notoriously difficult to control or treat. Costs include lost human labour, social care and medical expenses, reduction in livestock products and reproductive capacity, enforced herd slaughter, animal vaccination costs and lost income from livestock product sales. The number of human cases of brucellosis in Kyrgyzstan was reported to be 76 per 100,000 people in 2007, one of the highest in the world (Bonfoh et al. 2012), with prevalence higher than in neighbouring countries (Swinnen et al. 2011). An outbreak in 2012-13 resulted in bans on Kyrgyz dairy exports, depressing milk prices and costing the industry an estimated US$10,000 a day (Broka et al. 2016a). Test and slaughter programmes, progress in animal identification and a recent vaccination programme may help reduce prevalence and cases have dropped in recent years (Tilekeyev et al. 2016). In Kazakhstan, detected case rates in humans are 12 per 100,000 – which is still comparatively high (Broka et al. 2016b) and some sources suggest higher prevalence (Walker and Blackburn 2015).

Central Asia is a multi-drug resistant tuberculosis hotspot, with Kazakhstan and Uzbekistan amongst the 20 countries with the highest estimated number of cases and Kyrgyzstan and Tajikistan amongst the ten countries with the highest incidence per capita (WHO 2017c). The most common form of TB in people is caused by *M. tuberculosis*, however it is not possible to clinically differentiate these infections from those caused by *M. bovis*, which may account for up to 10% of human tuberculosis cases in some countries. This zoonotic form is transmitted through the consumption of contaminated milk, dairy products, or meat. In humans, there were an estimated 147,000 new cases of zoonotic TB and 12,500 deaths due to the disease in 2016 (WHO 2017c). Moreover, evidence suggests that the contribution of bovine tuberculosis to total global TB cases may be largely underestimated (Olea-Popelka et al. 2016). In Central Asia, the bovine form of the disease increased strongly in the 1990s (Pavlik 2008) but it is not clear how much of the current TB burden is related to the bovine form, as the disease is controlled by livestock vaccination to various extents in most republics. In Kazakhstan the last case in cattle was recorded in 2004 (Broka et al. 2016b).

Other economically important diseases and emerging threats

Foot and mouth disease is of primary economic significance as its suppression is an international requirement for export of livestock products (Walker and Blackburn 2015). Kazakhstan is the only Central Asian country designated as foot and mouth free, with partial vaccination continuing in border zones to prevent recurrence from abroad. In other countries the disease persists and was the major cause of import bans of Kyrgyz products by Kazakhstan and Russia in 2007 and 2011 (Broka et al. 2016b).

A number of emerging disease threats are of potential economic importance, including peste des petits ruminants virus (PPRV), reported in China and Tajikistan (Banyard et al. 2014). PPRV caused serious livestock and wildlife losses in Mongolia in 2017-8, almost wiping out the population of saiga antelope in that country (Pruvot et al. 2019). Outbreaks have been detected in Kazakhstan close to the southern border with Kyrgyzstan, and the disease is currently being kept at bay through vaccination (Kock et al. 2015). Seroprevalence appears to be high in Kyrgyzstan (Yapici et al. 2014).[16] The fact that these republics have not officially reported presence of this disease suggests poor surveillance and reporting. Lumpy skin disease is an economically important disease causing high mortality in cattle which has recently has spread from Africa and the Middle East, reaching Kazakhstan in 2016, where it has elicited a robust vaccination response (Calistri et al. 2020). Other republics may not be so well prepared and this disease has also been found to affect native antelope species (Kock, pers. comm.). Overall, transboundary disease spread is likely to be a serious issue in Central Asia. There is a lot of uncontrolled or illegal movement of livestock between republics and states such as Turkmenistan may become a regional health risk (Pannier 2019).

The positive contribution of animal health is clear for SDGs: at the farm level more healthy animals are more productive and are less likely to affect the health of their owners. At the national level, poor animal health has implications for consumers, national income from livestock, the health system more generally and the ability to export livestock products (see Topic 5). A regional approach including international agreements, decentralisation and partnerships with producer organizations, which was successful against FMD in South America, has been recommended (Walker and Blackburn 2015).

Major insights under Topic 4

1. *Improved animal breeds have made an important contribution to global livestock production and to the efficiency gains discussed under Topic 3.* Improved performance supports the attainment of SDGs 1 (no poverty) and 2 (no hunger), as well as supporting overall sector growth (SDG 8). But there may be trade-offs at the farm level through costs of the husbandry practices required to obtain full yield benefits and the environmental impacts of these practises. There are broader external costs in loss of genetic diversity if hardy breeds adapted to local conditions are neglected.

[16] The same authors also found high seroprevalence of Bluetongue Virus and Border Disease Virus which may also be also growing issues in Kyrgyzstan.

2. *Much of the genetic diversity and purity of breeds existing during the Soviet era has been lost or diluted due to uncontrolled interbreeding after independence.* Particularly in those republics where state farms were rapidly broken up, state and private animals intermingled and breeding controls on pastures, where animals mix freely, are few.
3. *New market signals led to changes in breed preference*. The new economic situation resulted in active selection of hardy or locally marketable breeds by farmers. Demand for some local breeds such as cashmere goats or Hissar sheep increased under changing market conditions, whilst other previously valuable breeds such as Karakul sheep, lost their markets.
4. *There has been renewed interest in improvement of animal performance*. Some republics have imported high yielding animals from the West or Russia. But there may have been a loss of focus on preservation of local breeds. There is no research reporting the results of breeding programmes in terms of uptake or on-farm economic outcomes.
5. *Disease poses a significant risk to livestock sector development in some republics.* Both FMD and brucellosis hinder development of export markets and the latter also threatens human health. The situation is improving in Kazakhstan but there are a number of emerging threats in the form of new diseases that may affect the entire region and which also have implications for wildlife conservation.

Research questions related to Topic 4

Research questions under Trade-off A. Commercialisation excludes smallholders.

1. *What are the trade-offs implicit in adoption of high yielding livestock breeds for different types of farm?* Is it more beneficial for smallholders to close the gap between actual and potential performance of local breeds than to adopt new ones and what are the trade-offs implicit in uptake of different breeds? This nexus concerns the economic costs of investments in improved husbandry and feeding, gains in animal productivity (target 2.3), and conservation of genetic diversity (target 2.5).

Research questions under Trade-off E Economic growth compromises production resources in agriculture.

2. *What is the impact of improving animal performance on the environment? To what extent does the use of high yielding breeds with specific husbandry requirements change farming and its environmental footprint?* These impacts could be felt through the ability of animals to use natural pastures, their feed requirements, and tolerance of extreme temperatures, which determine how the animals must be kept. Bio-economic trade-off analysis could be conducted on farms of similar sizes using different breeds, looking at SDG targets on vegetation and soils (15.3), water use efficiency (6.4), measures of land use and production efficiency (2.3, 2.4) and climate footprint (13.2).

Topic 5. Value chain development

Value chain development, poverty reduction and economic growth

Global demand for livestock products is predicted to increase strongly in coming decades (Delgado et al. 1999, Robinson and Pozzi 2011). If this growth can be captured, then the almost ubiquitous ownership of livestock by small farmers means that improvement of market access amongst this group has real potential for poverty reduction, and for synergies with other SDGs on inequality, food security and economic development (Delgado et al. 2008). Moreover, despite high frequency of livestock ownership, most developing countries are net importers of animal products. This highlights severe problems with domestic value chain development, but also represents an opportunity for growth (Otte et al. 2012).

Globally, in 2007 livestock accounted for around 35% of agricultural GDP, a figure closer to 40% in Latin America and Central Asia (FAOSTAT 2017, Otte et al. 2012). But the economic contribution may be underestimated owing to lack of accounting for certain benefits such as draught power and home-used manure (Behnke 2010). Livestock primary production and processing have both vertical and horizontal multiplier effects (return to initial investments at various stages of value chains) which ramify through household and national incomes. These multiplier effects are high compared to many other sectors and reach well beyond the agricultural sector –with increases in livestock production associated with greater expansion in non-agricultural sectors. For this reason, livestock sector development has been shown to be an important driver of GDP growth in developing countries (Otte et al. 2012, Pica et al. 2008).

Increasing market participation is associated with rising incomes. Thus, the poorest receive most of their livestock-related income directly from product sales whilst higher income households receive larger multiplier benefits from food processing and retailing. However, the relative benefits to lower-income livestock keepers from value chain participation are greater (Otte et al. 2012). On the other hand, the sector’s impressive growth performance is not always matched by corresponding reductions in rural poverty and increased smallholder labour productivity is essential if livestock growth is to reduce poverty though employment generation (FAO 2018a).

In this section, we look at the extent to which different types of Central Asian producer are able to access markets for their products. We survey research evidence on whether value chain interventions which improve market access and farmer productivity in other regions of the world (such as contract farming and cooperatives), also function in our region of interest. We also look at the integration of producers into global value chains through direct foreign investment and export and at how these developments relate to SDG goals.

Global value chains, vertical integration and contract farming

Value chains may be structured in a number of ways. Large-scale agro-enterprises may straddle the entire value chain from production to processing - an arrangement known as vertical integration. In contrast, farming and processing may be conducted by separate entities, but ‘vertically coordinated’ through contracts. However, many farmers access value chains through intermediaries or sell through ‘informal’ chains to small bazaars and to neighbours. In this section, we describe these different arrangements and suggest what experience from other regions of the world tell us about their impact on agricultural productivity and farmer incomes.

Vertical integration

Vertical integration is the capture of the entire production and processing process by a single enterprise. As discussed under Topic 1, such large agro-enterprises or agro holdings tend to be less efficient than individual farms. However, there are certain conditions which favour their development (Allen and Lueck 2004). Such agro-enterprises may monopolise supply in formal high-value chains or they may form a nucleus for service provision and market access to smaller farms. IFAD (2015) notes that smallholders linking to these large enterprises may access feeds, cold chains, machinery and technical expertise. Large enterprises may develop lands upon which production may be outsourced to smaller operations (Byerlee et al. 2015), although this does not appear to be common in the Central Asian livestock sector. In other situations, even smaller producers may vertically integrate, for example, where low margins on raw milk push producers into the processing business.

Contract farming (vertical coordination)

Swinnen et al. (2011) suggest that the development of modern procurement systems is often brought about through investments by multinational companies, which set their own quality and safety standards and build relationships with contracted farmers to obtain the quality and quantity of product missing on spot markets. Catelo and Costales (2008) suggest that increasing global integration of agricultural markets, trade liberalisation and growth of supermarkets in developing countries led to a rise in contract farming to the detriment of vertically integrated plantation operations, reducing risks to investments in large tracts of land by large agribusiness enterprises. From the farmer's point of view, contracts solve problems of marketing information asymmetry, access to technology and information on product requirements, and access to credit and insurance.

Swinnen and Maertens (2006) found that contracting arrangements grew fast in transition countries, with between 60% and 85% of farmers selling animal products on contract in a number of Eastern European countries by the end of the 1990s. In non-Central Asian CIS countries (Armenia, Georgia, Moldova, Ukraine and Russia), the proportion of food companies using contracts with suppliers was almost three-quarters by 2003. Assistance programs offered by contracting dairy companies included credit, inputs, extension services, veterinary services, transport and equipment (cooling). Even very small farmers may benefit: for example in Poland, where 85% of milk producers supplying to dairies by contract had a herd size of less than five cows (Dries and Noev 2005).

Economic benefits of contract farming.

There is strong global evidence that contract farming improves production efficiency (Otsuka et al. 2016b). Swinnen and Maertens (2006) find links with significant increases in annual growth in output and productivity in Eastern Europe. There is evidence from emerging economies worldwide that contract farmers in the livestock sector have higher profits per unit of contracted output and tend to be more profit-efficient at all scales, than independent farmers (Delgado et al. 2008). The willingness of contractors to pay a premium for certainty of supply during periods of growing demand has been demonstrated in several CIS countries (Sauer et al. 2012). Provision of veterinary services and cooling tanks has significantly improved the quality of milk, whilst credit and loan support allowed even large proportions of very small suppliers to invest (Swinnen and Maertens 2006). These authors also suggest more indirect effects through "*household and farm spill-overs*" which occur as risk reduction and stable income associated with contracts allows investment in other farm and non-farm activities. However, this is by no means universal and reviews suggest that, whilst income for contracted crops usually rises, change in total household income may be small or absent. This result is most likely to occur where contracted products are labour-intensive so that income from other agricultural products or nonfarm activities may be negatively affected (Meemken and Bellemare 2020, Otsuka et al. 2016b). The overall sector landscape is important in determining the levels of support to suppliers. The more competition between buyers (and thus less excusive the relationship with the farmer), the less likely the company is to provide support. In addition, internationally oriented buyers are more likely to invest in suppliers, illustrating advantages of FDI in the food production sector (Dries et al. 2012).

Equity effects of contract farming – when do smallholders benefit?

Contract farming affects equity firstly through distribution of rents in food supply chains, with evidence that farmers do benefit significantly from these arrangements (Swinnen and Maertens 2006). The second mechanism concerns participation rates of smallholders: if agro-industrial firms prefer to contract with wealthier farmers, then poorer households will be excluded from direct benefits. Contract farming may improve the competitiveness of large farms more than small ones, reinforcing the market dominance of the former (Delgado et al. 2008). However, it is often unclear whether small farmers are really driven out of markets or whether they upscale or move to better employment. Global reviews suggest a positive and significant effect of farm size on participation in contract farming, as larger scale producers are able to comply with increasingly stringent food safety standards and governments scale back support to smallholders (German et al. 2020, Narrod et al. 2010). But in some cases where this type of farm size effect was found, all of the sampled farmers were relatively small (Otsuka et al. 2016b).

In fact, different sets of factors may favour large or small suppliers. The transaction costs of contracting include identification and assessment of suppliers, contract negotiation, monitoring and contract enforcement, which all favour large producers (Key and Runsten 1999). The inability of small farms to invest and the fact that such farms require more assistance from the company per unit of output has the same effect (Swinnen and Maertens 2006). For this reason, the frequency distribution of farm size types in the overall production landscape is significant. Processors are more likely to work with small farms where these dominate the sector, than where they coexist alongside a reasonable number of large-scale operations (Catelo and Costales 2008, Dries and Noev 2005). On the other hand, smallholders sometimes have advantages over larger farms. Key and Runsten (1999) note that where credit markets are poor, companies may provide this service to farmers as part of contracts and, as small farmers are willing to pay more for credit, buyers can in effect purchase at a lower price. Where labour costs are high, firms benefit from the use of underemployed household labour, especially amongst small farms. Labour intensive, high maintenance production activities with relatively small economies of scale may thus favour smaller farmers. Even so, where land is expensive compared to labour, large farms have an advantage as land is underused on these farms (Key and Runsten 1999).

Most studies on contract farming focus on formal schemes with written contracts. But less formal schemes, often based on verbal agreements, are extremely common; the prevalence and benefits of these types of agreement should be a subject for further research (Catelo and Costales 2008, Meemken and Bellemare 2020). There are other mechanisms of high-value market integration such as agents, which are often producers themselves and play the role of intermediaries with dairy companies. Agents are supplied with equipment for testing and cooling, collecting milk from small village producers with whom they have informal contracts (Narrod et al. 2010).

Cooperatives

Service cooperatives can help farmers to access sales channels, and supply inputs, machinery, advisory services and credit. In the USA, cooperatives handle about 30% of total farm marketing volume and 28% of supply purchases of farms, in some European countries equivalent figures are over 70% and 50% respectively. Thus, in industrialized countries, they have contributed to the economic success of individual farms (Petrick et al. 2018). Cooperative membership is lower in developed countries, but the rise of vertical coordination has renewed interest because cooperatives may mitigate many of the scale-related obstacles preventing smallholder participation in contracting arrangements (Bijman et al. 2016). Case studies from across the developing world do indeed demonstrate a facilitation role amongst cooperatives for market access and compliance with technical standards (Otsuka et al. 2016b). In CIS countries, membership has been associated with slightly higher prices for milk - perhaps arising through the fact that these sales are also made through contracts (Sauer et al. 2012). But although many studies suggest that cooperatives can be highly beneficial to small farms, little is known about why they remain unusual in so many developing countries, nor about the conditions under which they are most likely to promote efficiency and equity (Otsuka et al. 2016b).

Value chains in Central Asia

Level of market participation and typical sales channels

As we saw in the first topic, livestock ownership distributions in Central Asia are characterised by a strong log normal distribution, characterised by large numbers of small producers and a few very large producers. Regarding the many small farmers, the first question concerns the extent to which these participate in markets at all, or whether their animals are kept more for subsistence and insurance purposes. For those which do sell produce, the second question concerns what channels are currently accessed by different types of producer.

Concerning the extent of market participation, Lerman (2004) suggests that true subsistence farming is rare in CIS countries, with the majority of households and farms selling at least some of their output. An observation from Kazakh survey data in the 2000s that over half of rural households sell livestock products of some type is probably still typical (Pomfret 2007). Market participation clearly varies strongly by location and survey data confirm the strong relationship between farm size and commercialization noted by Lerman (2004). Recent studies (presented in Robinson (2020)) found that close to the Kyrgyz capital, 60% of small farms and over 80% of large ones sold milk, with similar figures for live cattle sales. In more pastoral areas of Almaty oblast, frequency of dairy product sales was low and negatively associated with distance from the city, whilst probability of live cattle sales was strongly related to farm size (from 27% in the lowest quartile of cattle ownership, to 64% in the highest). At an Uzbek site in Kashkadarya, there were large differences in market access between households (of which 20% sold milk and 50% live animals or beef) and the commercial livestock farms of which almost 80% sold milk and 80% live cattle.

But not all forms of market participation are equal. We can distinguish between two major types of value chain, which we will call formal and informal. Informal types include sales directly to consumers at their homes, at local bazaars and unregistered shops, or to traders who sell on to those outlets. Such chains include home-processed unpackaged dairy products or live animals and are said to be the dominant form of food distribution (FAO Investment Centre 2010b, Naumov and Pugach 2019, Swinnen et al. 2011). More 'formal' value chains are those which end in processors or retail outlets such as supermarkets. However, many of these chains also have informal aspects in that sale may occur through intermediaries, or firms purchase from producers without contracts. Sellers of live animals in particular are often unaware of the end destination of their product (Tilekeyev et al. 2016) which means that farm survey data may capture little information about value chains.

Although the informal sector still accounts for the bulk of sales, there is evidence that formal value chains are expanding. The growing middle class in Central Asia prefers to buy processed and refrigerated dairy products from supermarkets rather than from bazaars. Whilst many of these products are imported (see section on Trade below), part of this demand is now met by local production. Even in Tajikistan, the poorest of the five republics, the volume of industrially processed dairy products in the city of Khujand saw a four fold increase from 2012 to 2014 in response to strong consumer demand (NIRAS 2017).

Despite growth in formal value chains, it appears that vertical coordination is rare in Central Asia. Few producers sell directly to processors, with the exception of large farms and enterprises. But even here, not all have contracts (see sections on beef and dairy value chains below). For the moment even in Kazakhstan, the only recorded large scale example of widespread private contract farming is to be found in the cotton sector (Petrick et al. 2017a), although Uzbekistan's new 'cluster' model (see Topic 1) attempts to create similar arrangements (Zorya and Babaev 2020). Here, private textile enterprises initiate clusters by submitting investment proposals to government. The winners are then guaranteed exclusive contracts with farmers, but must invest in them to improve cotton quality, soil and water management, and mechanization. It has been suggested that by eliminating the risk of side-selling this arrangement favours these investments, which would reflect the observations of Dries et al. (2012) mentioned above, that a monopsony can favour contract farming. The cluster model may be extended to other sectors, including livestock production.

Outside the cotton sector, reasons suggested for the low prevalence of contract farming include lack of trust. Contract breaches are common and legal systems weak, unreliable and costly (Swinnen et al. 2011), although the right mixture of incentives and sanctions can help make contracts self-enforcing (Gow and Swinnen 2001). Absence of FDI is a second possible barrier, as international companies are more likely to push for contract farming or provide support for cooperatives (OECD 2015, Swinnen and Maertens 2006). Finally, the fact that many processors work below capacity suggests that large suppliers are absent and transaction costs of working with small producers are high. These problems are rooted in the scale and production capacity of farmers themselves and include insufficient feed supply, administrative barriers to land consolidation and poor animal health and food safety systems, which investors cannot address themselves (FAO Investment Centre 2010d, Swinnen et al. 2011). It is possible to imagine that vertical coordination could damage smallholders if large companies prefer to contract with a small number of very large farms, with the loss of trader-based systems which currently reach out to large numbers of producers.

Although we suggest here that contract farming is rare in the Central Asian livestock sector, less formal types of vertical coordination based on verbal agreements, are common in many developing countries (Catelo and Costales 2008). It is possible that the same is true in Central

Asia but the prevalence, nature and benefits of such arrangements are understudied in the region.

Dairy value chains

There are three main types of dairy value chain including (i) home processing for self-consumption and sale to neighbours and traders; (ii) localized dairy plants collecting milk from nearby villages; and (iii) large dairy processing plants able to collect milk from a large area but also using imported powdered milk (Oshakbayev and Bozayeva 2019).

In Kazakhstan, due to vast distances and disbursed populations, localised dairy plants are rare and such small plants lack investment and often have only basic packaging facilities. Their number is said to be declining, whilst large plants in cities account for an increasing share of processing (FAO 2011a). Yet even in areas with processing capacity, the majority of individual farms sell milk through independent intermediaries (Petrick et al. 2014). Large farms are more likely to sell to processors directly but few have contracts and levels of support provided are much lower than those in the above-cited studies on Eastern Europe (Petrick and Götz 2019).[17] Some international companies have established cooling tanks in villages and send their own cooled tankers to collect milk. This is achieved through active local farmers who have a contract for cooling equipment and milk supply and form the link with the processor for the whole village (similar to the agent system described in the introductory section on contract farming above). There are also cases of milk collection points or cooperatives operating as separate businesses but these are said to be less successful (FAO Investment Centre 2010b). New subsidies for cooperatives since 2016 finance 50% of investments in milk storage and processing equipment, but the success of these has yet to be fully evaluated (OECD 2019b). Overall, investment decisions made by the processor have an important influence on the ability of smallholders to access value chains.

Notwithstanding the above examples, the existence of collective infrastructure at the village level for cooling or freezing is rare in Central Asia and indeed IFAD (2016) identifies this as the main difficulty in linking farmers to dairy value chains in Kyrgyzstan. Here, in peri-urban areas such as the Chui valley, milk producers of all scales sell to processors near Bishkek through a chain of village-level traders, a system well developed enough that few farms sell through any other channel. It also seems profitable enough for producers that they tend not to sell home processed products themselves (Niiazaliev and Tilekeyev 2019). But agreements between farmers and traders are verbal and traders purchase door to door rather than from a central cooler. Where connections between smallholders and processors are weaker, small farms and households are more likely to process raw milk into less perishable products for sale through informal markets (Kosimov 2018, Naumov and Pugach 2019).

In Tajikistan, the fragmented structure of milk production means that larger dairy processors often have to work well below capacity, especially in winter. The country has around 55 large dairy processors and many have to import milk powder for re-constitution into ice cream and milk (NIRAS 2017). But these issues are by no means confined to Tajikistan. Even in Kazakhstan, it has been estimated that 25% of dairy products are imported, with powdered milk for reconstitution predominating (Oshakbayev and Bozayeva 2019). Domestically produced milk

[17] This study also included farms in Russia

can be competitively priced compared to powdered milk, but the supply of milk of sufficient quality is limited (FAO Investment Centre 2010b).

In Uzbekistan, processing capacity is said to be well distributed, with few districts lacking dairy plants (IFAD 2015). Yet value chains are sharply divided into two types, with households selling processed products through informal markets and milk going to processing enterprises coming mainly from private farms and agricultural enterprises (Naumov and Pugach 2019). Few of the farmers surveyed in that study had contracts, but IFAD (2015) suggest that most commercial sales are on a contractual basis and that processors may pre-finance the installation of a cooling tank on-farm or provide technical assistance and training. The same report cites at least one case of a large multinational buying from both large and very small farms. Government policy supports village milk collection centres (Naumov and Pugach 2019) and IFAD (2015) has invested in these under various ownership models so there may be a future for smallholder integration into Uzbek dairy value chains.

Following the 2009 President's Decree offering revenue tax exemption to farming enterprises with processing facilities, some dairy farms have invested into processing. Since then, a 2017 decree makes vertical integration of production and processing obligatory (Naumov and Pugach 2019). IFAD (2015) predict that such vertically integrated companies are likely to be uncompetitive and we note that elsewhere, milk production and processing tend to be conducted by separate actors (Dries and Noev 2005).

Concerning margins, most analyses compare individual farms, intermediaries or processors and are rather anecdotal. Intermediaries are considered particularly profitable, as their risks are minimal IFAD (2015). Competition may result in high prices for farmers (IFAD 2016) but cartel behaviour amongst traders has also been observed (Niiazaliev and Tilekeyev 2019). Work by the FAO in Kazakhstan found that among registered farms, medium-scale dairy operations were most profitable. The same study found that households have far lower costs, but these do not include labour, and product quality is very low, limiting choice of sales outlet (FAO Investment Centre 2010b).

In all republics, milk prices depend primarily on fat and protein content, with highest quality milk being 38% more expensive than lowest quality in Kazakhstan (Oshakbayev and Bozayeva 2019). The quality of milk from smaller operations tends to be lower - for example, in Uzbekistan mean fat content of milk produced by households is 2%, whilst the equivalent figure amongst individual farmers is 3.2-3.5%. Here, for processors levels below 3% are unacceptable, but may still be prevalent in bazaars (IFAD 2015).

Hygiene standards are also very different between processors and informal outlets. Kazakh milk quality standards, based on international norms, include criteria based on acidity, bacteria count, somatic cell count and density. But the majority of dairies limit their controls to dry matter, fat content and acidity whilst products marketed in bazaars are even less controlled, if at all (FAO Investment Centre 2010b). In Uzbekistan, the two-tier sanitary control system is similarly stricter for products processed industrially than for those sold on the market. The result is unfair competition, with modern dairies unable to obtain sufficient quantities of high quality raw milk, whilst lower-quality milk is sold elsewhere (FAO Investment Centre 2010b, IFAD 2015). In other parts of the region, the hygiene standards are perhaps worse still, with buyers checking only for water addition and acidity (IFAD 2016) or conducting visual inspection alone (Kosimov 2018). A major source of contamination is the storage and transport of milk which, as we have seen above, would be mitigated by village level coolers and cold chain infrastructure.

Beef value chains

Globally, commercial beef systems are usually split into sequential stages. For example in the USA, cow-calf operations produce calves for sale, which then gain weight on grass in stocker farms. A feedlot operation (usually located in the grain belt) then brings them to slaughter weight of 400-600 kg at 12-22 months of age (Crespi and Saitone 2019, Lowe and Gereffi 2009). In Europe there is a range of feeding and production systems, but again stages located in different farms are common (European Commission 2013, Hocquette et al. 2018). There is little vertical integration in the beef industry, in contrast with pork or poultry production. A major reason is the amount of land that is necessary to graze cattle (Crespi and Saitone 2019, Lowe and Gereffi 2009). For one company to undertake the entire cattle life cycle including calf production, stocking, feedlot, slaughter and processing requires large amounts of capital; each stage having different resource and management needs (Nin et al. 2007). Longer biological cycles, the spatial extension of grazing and the long history of genetic improvement leave less room for cost savings from vertical integration in beef than in other meat chains (Crespi and Saitone 2019).

In Central Asia, the separation of beef production into clear stages as described above is less common. The finishing phase is often missing and specialisation in production of weaners (cow-calf operations) appears to be rare. Instead, most producers raise cattle from birth, selling them at various ages according to need. Typically, famers will look to fatten a cohort of animals on summer pastures for sale in autumn (for slaughter or further fattening elsewhere); whilst those with the best access to high quality winter feed may then fatten them further on grain for sale in the winter. Stall-feeding of a small number of bullocks from birth is also practised by smaller or peri-urban producers with little access to pastures. Some farms follow very heterogeneous strategies, for example raising the majority of animals to slaughter weight on pasture, with a subset then finished on grain. Specialist finishing operations, both industrial and small scale, do exist but farmers may be unaware of sale to these as there are so many intermediaries in value chains.

Beef value chains are complex, involving markets, traders, abattoirs, feedlots and retailers. Whilst for farmers, primary sales channels for live animals are local traders and district markets, few producers are able to sell directly to regional markets, feedlots or large processors (Robinson 2020). In contrast, large enterprises (in Kazakhstan) sell predominantly to processors and export markets (Petrick et al. 2018). Across the region, a lack of local certified abattoirs is a constraint, which is one reason why so many farmers sell animals live in markets or to mobile traders (Niiazaliev and Tilekeyev 2019, Petrick et al. 2014).

The majority of literature on beef production concerns Kazakhstan, where the OECD (2013) has classified value chains into two types. Short chains include sales by producers, via traders to wholesalers and retailers at bazaars with costs comprising transport, slaughter, laboratory testing and market entry fees. Traders may purchase meat slaughtered by the owner (which is illegal) or get animals slaughtered at a local facility, selling the meat to wholesalers at the bazaar, or directly to shops or restaurants. Meat in bazaars is subject to veterinary inspection, but traders may also sell cheaper uninspected meat. The majority of meat in these chains is sold fresh, chilled meat is virtually absent.

Longer chains to supermarkets entail greater inspection costs at slaughter, and wholesaler costs such as cold storage, packing or processing. However, the selling price at end point is higher and product quality is also greater, which is important to urban consumers. Some supermarkets contract directly with large individual farms or agricultural enterprises, allowing them to control quality (OECD 2013). In other cases, abattoirs at city markets are the key hub in the chain, often purchasing large numbers of animals live, slaughtering and selling the meat on to retailers. One advantage of selling to certified abattoirs or processing facilities is that it renders the producer eligible for the output subsidy on meat, not available in the shorter informal chains - but the commission taken by such abattoirs is also high.

One reason suggested for the persistence of short value chains is the poor domestic road network (of which one indicator is the very large differences in beef prices recorded across the country (FAO, 2010b)). Yet live animals may be transported over vast distances. This may be due to lack of village slaughter facilities and cold chains, or because animals are purchased for fattening and transported to areas where feed is cheap (Robinson 2020).

Some large agricultural enterprises have integrated grain production, the cow-calf operation, grazing, feedlot, slaughter and packaging in a single operation (FAO Investment Centre 2010d, OECD 2013). As mentioned above, such vertical integration is unusual in beef production and possible factors, such as government support, behind this development is of research interest. Processors without their own herds often complain that that the main problem is inadequate meat supply - causing them to operate below capacity. They react to this by importing beef, although this has become more expensive due to introduction of quotas. Whilst little has been written on the subject, it appears that although large multinationals have invested in the Kazakh dairy sector, investors in large commercial beef farms have largely been Kazakh. However, international companies looking for routes to access large Chinese markets may change this pattern (Meyer 2019).

Feedlot development

The development of feedlots has two important synergies with other SDGs. Firstly, the practise minimises GHG emissions per kg of product by fattening quickly on highly digestible feed for the last few months before slaughter (Wilkes and Merger 2014). In addition, it may be used as a mechanism to integrate smallholders into value chains. However, the longer the feeding period, the greater the trade-offs for arable land use efficiency, food security and water pollution (see Topics 3 & 7).

Little systematic research has been conducted on feedlot development in Central Asia. Kazakhstan is investing in development of industrial scale feedlots for finishing cattle raised on grass. The country's strategy for beef development (Ministry of Agriculture of the Republic of Kazakhstan 2018) lists 30 industrial feedlots, most having between 3000 and 5000 lots and holding a total of 134,000 cattle. Some investments go way beyond finishing and raise cattle from 6-7 months, feeding them for one year starting at 200-220 kg and slaughtering at 450-500 kg (FAO Investment Centre 2010d).

The economic viability and technical efficiency of highly capital-intensive feedlots is questionable and it has been calculated that medium or small operations are likely to have higher margins than very large capital intensive ones (FAO Investment Centre 2010d). Vertical integration with other stages is said to be feasible if a significant part of nutrition consists of grazing and feed is cheap (prices in Kazakhstan fluctuate strongly with the grain harvest). Obtaining access to the necessary areas of pasture for the grazing stage is problematic, as most easily accessible areas are already leased. Vertical coordination may be more efficient, with feedlots purchasing animals from cow-calf or stocker operations as in the USA. This would be positive from the point of view of integration of farmers into value chains, but poses sanitary risks for the feedlot.

Vertical coordination may also be problematic as, in spring, farmers may prefer to hold on to their animals for cheap weight gain on summer pastures, so that feedlots are likely to be competitive buyers for animals only in the autumn (FAO Investment Centre 2010d).

In addition to industrial feedlots, many animals are fattened in small home-based outfits close to cities, or in middle-sized operations, of which there is a cluster in southern Kazakhstan. However, there is no information about the volume of beef going through these different channels, in particular the smaller establishments. In Kyrgyzstan, the feedlot industry is developing and 9% of beef cattle are said to be finished in such establishments (Wilkes and Merger 2014). There are said to be around 500 feedlots in Chui oblast and it has been estimated that 50% of outgoing cattle are sold live into the Kazakhstan market illegally (ibid.)

Sheep value chains

Value chains for sheep meat are similar in many ways to those of beef. Tilekeyev et al. (2016) conducted a detailed study on these chains in Kyrgyzstan and found that, as with cattle, sheep tend to be sold via intermediaries. Abattoirs are often themselves intermediary suppliers of meat to wholesalers or retailers but most have extremely low capacity and lack refrigeration equipment. Veterinary compliance and food safety (discussed above) are an important barrier to export, but not the only one. Most sheep production is oriented to the domestic market which prizes consumption of adult sheep meat with a high fat content. Animals are usually marketed on their return from the summer pastures although some farmers or intermediaries may subsequently fatten them for a further one to two months. Limited winter fodder results in mass autumn destocking, creating an oversupply of sheep meat in autumn and low supply in spring. Thus, surplus for export exists only in autumn and winter, which may also be an issue for pasture-based beef production.

Trade in livestock products

Regional and global trading arrangements

The export of livestock products is an aim that regularly appears in government strategy documents across the region. Export of food products from Central Asian states has grown in absolute terms, although its relative importance compared to other exports (and to domestic production) has not. Grains, fruit and vegetables dominate food exports, whilst livestock products play a small role (Mogilevskii and Akramov 2014).

All Central Asian states except Turkmenistan are members of the Commonwealth of Independent States Free Trade Area (CISFTA), a free-trade area comprising the bulk of former Soviet states. Both Kazakhstan and Kyrgyzstan are members of the more deeply integrated single market and customs union of the Eurasian Economic Union (EAEU) and as such should have unfettered access to agricultural markets with each other, Russia, Belarus and Armenia. Kazakhstan is also conducting negotiations on harmonisation of veterinary and phytosanitary standards with Iran and Saudi Arabia, where demand for meat is strong (Ministry of Agriculture of the Republic of Kazakhstan 2018, OECD 2019a). These efforts include animal identification; abattoir improvement; and disease control programmes, recently rewarded by international recognition of Kazakhstan as a foot and mouth disease free zone (Oshakbayev and Bozayeva 2019).

At present, all Central Asian republics are WTO members except Uzbekistan, which plans to join, and Turkmenistan, which has not yet applied. Tajikistan and Uzbekistan benefit from favourable access to the EU market through the Generalised Scheme of Preferences (GSP),[18] whilst the Kyrgyz Republic benefits from additional preferences through the GSP+ scheme.

The Russian import embargo of food products from Western countries in August 2014 further opened up possibilities for Central Asian countries to expand agricultural exports to Russia. The ban includes all imports of livestock products from the European Union, United States, Canada, Australia, and Norway (Bobojonov et al. 2016). Swine flu killed 40% of China's pig population in 2018-19 (Huang 2020), which created both a deficit in meat in China, and export opportunities in Central Asia, in particular for Kazakhstan.

Trade in livestock products: volumes and trends

Figure 12 presents trade figures for livestock and livestock products. In general, exports are dwarfed by imports, many of which concern packaged dairy products. In Kazakhstan, although beef supply roughly covers domestic demand, many processed products are imported and national statistics suggest that poultry made up around 70% of meat imports in the last few years, with beef accounting for most of the rest . To satisfy the lack of local supply to processors mentioned above, cheap ingredients are imported, including powdered milk for reconstitution and beef trimmings, costing half the price of local meat (FAO Investment Centre 2010d). More recently, Tariff Rate Quotas (TRQs) have been applied to beef and there are indications of recent export growth. Although still dwarfed by imports, total export value of meat and meat products (which are dominated by beef) grew strongly in 2018 and 2019 (Figure 12a), probably linked to meat deficits in China. There is also evidence that exports are increasing to other countries in the region such as Uzbekistan (MeatInfo 2019).

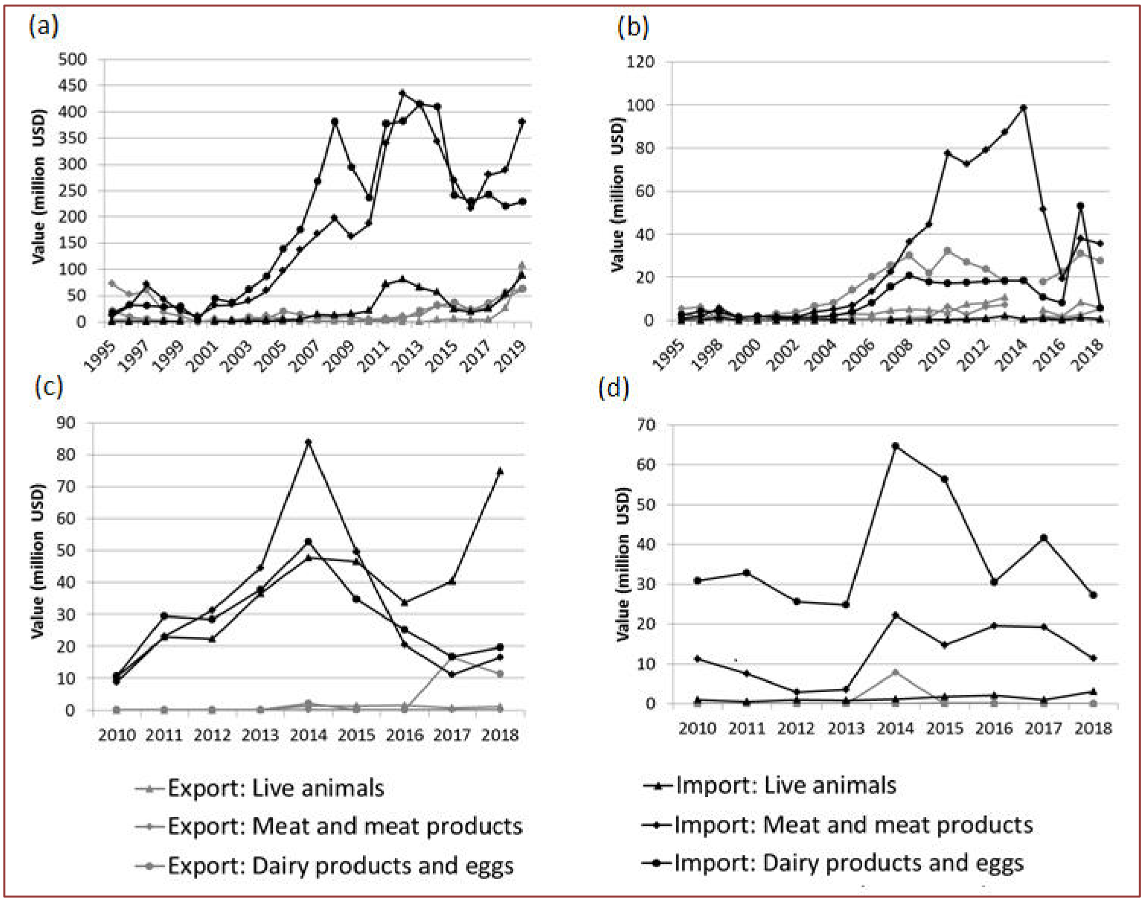
In Kyrgyzstan, from about 2005 to 2010 there was strong growth in milk and dairy exports, which were almost all sent to Kazakhstan for processing (Zhunusova 2017). This then stagnated, particularly in 2013, due to disease outbreaks but is now recovering. Milk products are one of the top five agricultural exports making up 82% of all livestock sector exports by value (IFAD 2016). Exports of live animals, almost zero before 2004, generated almost ten million USD in 2013, but numbers were underreported and many more were smuggled into Kazakhstan. At the same time, imports of meat and processed meat products are consistently much larger than all exports and increased year on year to 2014 (Zhunusova 2017). Since then, these imports, as well as exports of livestock, have declined (Figure 12b).

Since accession in 2015, Kyrgyzstan should theoretically have been benefitting from EAEU membership and indeed Russia and Kazakhstan are its largest trading partners (Zhunusova 2017). But benefits for the livestock sector are yet to be fully realised. During accession, the Government of the Kyrgyz Republic approved phytosanitary rules and veterinary and sanitary requirements to prevent animal diseases. But most abattoirs still fail to meet EAEU sanitary norms (UNIDO 2018). The current bio-laboratory infrastructure lacks equipment, skills and capacity and is unable to issue quality certificates to exporters (UNIDO 2018). In 2016, these issues resulted in a ban on transit of meat and milk (from certain enterprises) via the territory of Kazakhstan. Deliveries of raw meat and livestock continue to be subject to prohibition (O'Connell and Kiparisov 2018), although some dairy enterprises gained licences to export products

[18] For details on this scheme see https://ec.europa.eu/trade/policy/countries-and-regions/development/generalised-scheme-of-preferences/.

within the EAEU. Likewise, food safety problems mean that benefits from the EU GSP+ scheme have been limited to non-livestock products. But membership of the EAEU has spurred some concrete steps towards modernization and commercialization, including establishment of a system of animal identification.

Figure 12. Trends in import and export of livestock and livestock products (a) Kazakhstan; (b) Kyrgyzstan; (c) Uzbekistan; (d) Tajikistan (value, million USD).



Sources: Kyrgyzstan and Kazakhstan: UN Comtrade International Trade Statistics Database, SITC classification. Tajikistan and Uzbekistan: FAOSTAT.

Both Tajikistan and Uzbekistan export few livestock or livestock products, although Uzbekistan's dairy and egg exports have grown in recent years (Figure 12c & d). Dairy imports comprise mainly non-traditional products such as butter, yogurts and cheese (Naumov and Pugach 2019) but a 30% tariff on milk powder limits imports of this product (IFAD 2015). Recent years have seen strong increases in all livestock product imports, in particular of live animals (Figure 12c). Imports of live pedigree cattle from Kazakhstan (where these are subsidised) has been seen in that country as a subsidy transfer to Uzbekistan (Kazakhstan Chamber of Commerce 2020). In Tajikistan, dairy and eggs dominate imports of animal products and it is estimated that the 'retail' market for dairy consists of almost 25% of imported products. As customs procedures are difficult and expensive it is also likely that more are imported unofficially (NIRAS 2017).

The extent to which individual farmers or households benefit from export markets and determinants of participation have been little studied in Central Asia. Bobojonov et al. (2016) found that amongst individual farms in Uzbekistan, willingness to increase production of exportable commodities was associated with institutional factors such as fertilizer subsidy, cooperative membership, quality control, contracts and insurance. In Kyrgyzstan, the probability of export participation was found to be determined by geographical location, allocation of labour to agriculture, and the production of exportable products. But significant benefits for household welfare (compared to participation in domestic markets) were not detected, because export occurs through intermediaries whose power to dictate prices in local and regional markets is overwhelming (Esenaliev and Teichmann 2013).

The role of cooperatives in market participation

In the sections above, we have seen how private intermediaries are extremely important in meat and dairy value chains. Service cooperatives could potentially replace these intermediaries, supporting small farmers in marketing, processing, input supply and access to credit, machinery and agricultural extension. Farmers may benefit from economies of scale, increased bargaining power and greater efficiency. Moreover, it is easier and cheaper for governments to provide assistance through co-operatives. Some multinational companies have supported cooperative development, as it is easier for them to work with groups of small farmers (OECD 2015).

Yet their development in Central Asia lags behind that in the rest of the world (Lerman and Sedik 2014). In European countries, the vast majority of farmers are registered members of at least one cooperative (OECD 2015), whilst in Kazakhstan the number of cooperative members is around 3.4% of farm holdings. Moreover, these cooperatives are not at all comparable to those in the West, which are understood to be service cooperatives (Djanibekov et al. 2015). In the former Soviet Union, the word ‘cooperative’ evokes the idea of a production cooperative or collective farm, in which farmers effectively lose power over production decisions (Lerman and Sedik 2014). Such cooperatives are both unattractive and inefficient (Petrick et al. 2018). But service cooperatives have also been made unattractive in some cases, particularly when VAT rules lead to double taxation of members (Sedik and Lerman 2015).

In Kyrgyzstan, cooperatives are few and many exist only on paper (Lerman and Sedik 2017a, O'Connell and Kiparisov 2018). Most are production cooperatives, although these partially fulfil the function of service cooperatives by providing services to non-members (ibid.). IFAD (2016) suggest that collective efforts to organize marketing in the livestock sector appear limited to externally supported interventions, although the government does have new plans to link support to cooperatives formed around processing enterprises (O'Connell and Kiparisov 2018). Tajikistan passed a law on cooperatives in 2013 with the intention of facilitating rural service provision, but this does not fully distinguish between production and service cooperatives (Lerman and Sedik 2014). Tax code provisions exempting cooperatives from profit tax and VAT exist, but could be improved (Lerman and Sedik 2014).

In Kazakhstan, cooperative formation has been encouraged through loans and subsidies for members, who individually would not meet scale criteria for receipt (OECD 2015). Some of these subsidies were provided for larger investments, such as milk collection points and abattoirs (OECD 2019b). Government targets aimed to expand membership from 41,000 in early 2017 to 500,000 by 2021 (Petrick et al. 2018). But whilst there was a burst of cooperative registration following improved legislation in 2015, it has been estimated that 60% of these are ‘false’ or inactive cooperatives existing solely to gain access to subsidies (OECD 2019b).

Recommendations suggested for Kazakhstan (but probably relevant to all republics) include reforming the legal framework and tax code, simplifying registration procedures, providing information services and technical assistance, greater financial support for cooperative establishment, and building on other collective action mechanisms, which can often be precursors to cooperatives (OECD 2015, Petrick et al. 2018). Recent developments in Kazakhstan suggest progress in legislative development and education programmes, but the prevalence of false cooperatives and lack of mobilisation of internal funding suggests that a true grassroots cooperative movement has yet to emerge (OECD 2019b). On the other hand, successful examples do exist and documentation of these, as well as other forms of collective action, would help identify models that work in the Central Asian context (Djanibekov et al. 2015).

Major insights under Topic 5

1. *Growth in global demand for livestock products represents an opportunity for smallholders to increase their incomes.* But benefits depend on access to increasingly complex value chains by this group.
2. *Vertical coordination in transition economies has potential to increase productivity, incomes, employment and economic growth.* There are cases in Eastern Europe where even very small farmers have been well integrated into value chains and this process has been shown to be beneficial to suppliers.
3. *The successful participation of smallholders in vertical coordination depends on a number of conditions*. Factors such as the overall distribution of farm sizes, transaction costs of working with small farmers, legal and institutional environment and severity of competition for supplier will affect the extent to which small famers can participate, and the type of arrangement offered. But this information comes from literature outside Central Asia. The costs and incentives for engaging in contract relationships and determinants of their success or failure are poorly documented in the region.
4. *In Central Asia, the majority of producers sell through 'informal' channels such as to traders and bazaars; most products sold are home-processed and unpackaged.* Even within more formal value chains to supermarkets or processors, contracting is unusual. Sale of milk to processing firms is most common amongst farmers located near cities but even these producers tend to sell informally through traders. In meat marketing the predominance and number of intermediaries hinders understanding of the proportion of meat going through different channels.
5. *Explanations proposed for the lack of contract farming include lack of trust, dearth of foreign investment and animal health issues.* FDI often stimulates contract farming but may be lacking if the legal and institutional environment is weak. Poor animal health and food safety systems block export prospects and dissuade investment in the sector.
6. *Processors are unable to source sufficient volumes of quality raw product.* Some of the barriers to commercialisation of the livestock sector are rooted in farm scale and production issues such as pasture access, feeding and obstacles to land consolidation. The difference is often met through imports.
7. *Processors suffer from lack of investment.* Milk products sold in markets are not subject to the same standards as those for milk sold to processing companies, meaning that it is difficult for the latter to compete on price. The sanitary condition of small or local

plants is often poor and processors lack investment, modern equipment and marketing skills.

8. *Service cooperatives could potentially link farmers to firms by covering transaction costs, but so far these institutions are weak in Central Asia*. There is a lack of distinction (both in minds and in legislation) between producer and service cooperatives, born of the Soviet collective farm experience. Inappropriate tax frameworks penalise service cooperatives in some republics.

9. *Absence of cooling equipment at village level has been described as the single biggest obstacle to smallholder participation in dairy value chains.* In remote areas, absence of district level dairy plants and abattoir facilities for beef value chains are also an issue, at least in Kyrgyzstan and Kazakhstan.

10. *Central Asian countries are net importers of livestock products.* Due to the problems outlined above, many high-value livestock products are imported. There is thus great potential for import substitution through development of value chains with greater added value, with benefits along the entire chain.

11. *Integration of the livestock sector with global value chains is poor.* Here, the major reason is animal health and product safety. Only Kazakhstan can realistically hope to export large volumes of livestock products in the near future although Kyrgyzstan is also making progress.

Research questions related to Topic 5

Research questions under Trade-off A. Commercialisation excludes smallholders.

These questions centre on the nexus of poverty reduction (1.4), access of smallholders to productive resources and markets (2.3), economic growth and innovation (8.4) and employment and income (8.5).

1. *How successful are cooperatives, private intermediaries, processors and government-sponsored milk collection centres in facilitating vertical coordination in dairy value chains?* A comparison of these different models of milk aggregation could examine both inclusiveness and costs and benefits for participating farmers of each model. In particular, there are research gaps on the benefits of cooperative membership and on viable cooperative models.

2. *How prevalent are contract farming arrangements among producers in Central Asia? What are the determinants of participation (including firm and farm characteristics) and to what extent do participating farmers benefit?* This study could include an assessment of benefits and trade-offs of vertical coordination for firms and different scales of farm. Informal arrangements resembling vertical coordination are particularly poorly addressed in the literature and should be included in such a study.

3. *Is beef value chain development likely to lead to vertical coordination or vertical integration? What are the social and economic costs and benefits?* To what extent are feedlots developed in Uzbekistan, Kyrgyzstan and Kazakhstan? Are they vertically integrated (having their own herds), or do they rely on supply of cattle from smallholders? What is the future potential for integration of smallholders into formal value chains?

4. *What will be the SDG trade-offs of current reform in Uzbekistan on livestock value chains?* The obligation to invest in processing and new 'cluster' policies may have a profound impact on livestock production and value chains. Kyrgyzstan has also attempted to tie access to subsidized credit to formal value chain participation. To what extent do these policies favour (or inhibit) value chain development and social/economic objectives?

Studies on trade-off E between economic growth and environmental goals are listed under Topics 2, 3 & 7.

Topic 6. Human diet and health

Diets in many developing countries are characterised by an increasing consumption of foods high in fats and sugars and relative reduction in the share of cereals and fibres such as fruit and vegetables. Outcomes include increases in non-communicable diseases (NCDs) such as heart disease and diabetes, and may also be associated with micronutrient deficiency which lowers immunity to infectious diseases (Hawkes 2006). Yet these new forms of malnutrition coexist with food insecurity and undernourishment. Referring in particular to SDG indictor 2.2, we look at these two co-existing forms of malnutrition in Central Asia, examining current levels, trends and trade-offs between economic and food security goals and dietary change, particularly in the livestock sector.

The global nutrition transition

The nutrition transition (Popkin 2003, 2006) begins with two stages of dietary characteristics associated with hunter-gathering and primitive agriculture. The last three stages are more relevant to modern development processes and occur in tandem with related demographic changes towards lower fertility and mortality (Figure 13). Stage 3 is characterised by receding famine and improvement in indicators of severe undernutrition. This is followed by increases in consumption of fat (especially from animal products), sugar, processed foods and a drop in fibre (stage 4). Associated with a drop in physical activity, this dietary change leads to increases in non-communicable diseases such as heart disease and diabetes. Educational and cultural changes subsequently lead to dietary improvements and increased physical exercise, with associated health improvements (stage 5).

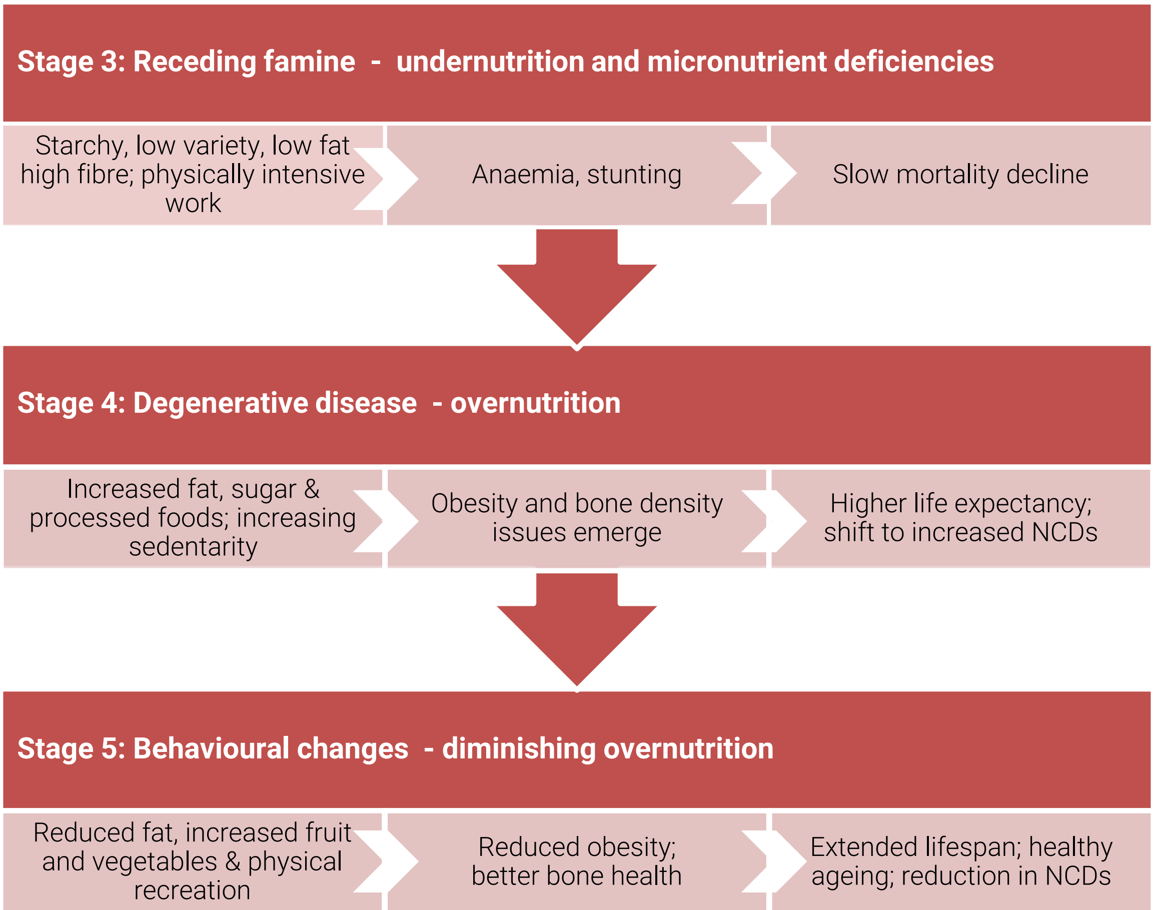
Empirical data suggest strongly that in middle income countries at stage 4, there is a *positive* relationship between income and educational attainment, and health problems such as obesity – as people with higher socio-economic status are better able to afford energy dense and processed foods. However, as countries reach stage 5, this relationship often inverses, with poorer households having higher levels of obesity and related NCDs (Templin et al. 2019). This may be related to affordability or availability of healthy food (Darmon and Drewnowski 2008), awareness of the benefits of good diet and physical activity, or cultural factors affecting the propensity to exercise and perception of obesity (Rguibi and Belahsen 2006) - see also references and discussion in FAO (2019).

Concerning the role of the livestock sector, livestock products have high income elasticities[19] compared to many other foods, in particular in regions where per capita consumption is low (Gehlhar and Coyle 2001, Robinson and Pozzi 2011). The steep rise in global meat and dairy consumption associated with increasing incomes has been called 'the livestock revolution' (Delgado et al. 1999, Steinfeld et al. 2006). In developing countries meat consumption has been growing at 5% per year and milk products at 4% (FAO 2006). Red and processed meat can be particularly harmful to health, with overconsumption linked to coronary heart disease, stroke, certain cancers, and type 2 diabetes. However, three quarters of the global disease burden from these products is linked to processed meat (Springmann et al. 2018). Disease impacts from unprocessed red meat are more debatable and according to sources in the review by Neumann

[19] The increase in demand for a product which results from an increase in income. In some region of the world certain livestock products have an elasticity of demand greater than one, implying that a one percent increase in income will lead to an increase in consumption of more than one percent.

et al. (2010) differences between lean or fatty meat may be as important as overall consumption in determining health outcomes.

Figure 13. Stages 3 to 5 of Popkin's Nutrition Transition



Source: Adapted from FAO (2017).

Trade liberalisation has meant that other forms of fat intake also rise steeply: for example between the early 1980s and 2000s vegetable oils contributed more than any other food group to the increase of calorie availability worldwide, largely due to liberalisation in soybean export and import policies across the world (Hawkes 2006). Hydrogenated forms of these oils lead to the creation of trans fats, which increase the risk of coronary heart disease. Multinationals have been key to the spread of highly processed foods in countries such as Mexico, resulting in steep growth in production and consumption of processed snacks and dairy products. These products are directly consumed and also change dietary habits and aspirations, stimulating production of similar foods by local companies (Hawkes 2006).

In many developing countries, these new dietary problems occur alongside persistent undernourishment, severe food insecurity, and childhood stunting and wasting amongst poorer households (SDG 2.2). Neumann et al. (2010) note that the livestock revolution has not yet arrived in many parts of the world and that 30% of people in developing countries suffer from multiple nutritional deficiencies. Here, the livestock sector has a positive role to play - as the rural poor and landless tend to earn a higher share of their income from livestock than wealthier rural residents (Delgado et al. 1999). The high bioavailability of protein, iron and vitamin A in animal products could reduce the loss of the millions of disability-adjusted life years (DALYs) attributed to deficiencies in these three elements. In particular, the high digestibility and density of animal proteins and minerals make ASFs important for those with limited food intake capacity relative to their needs, such as young children and pregnant or lactating women (Otte et al. 2012).

Accordingly, many studies link access to livestock products with improved childhood nutrition (Braun and Panya-Lorch 2003, Tangka et al. 2000).The review by Neumann et al. (2010) finds several studies demonstrating links between ASF consumption and growth, birth weight and cognitive development in children. Meat and fish are particularly important as, whilst dairy products can compensate for lack of protein and vitamin B12, they cannot do so for iron and zinc. Livestock also contribute indirectly to food security and nutrition through manure for crop production; their role as a buffer mitigating the impact of fluctuations in crop production; and as a source of ready cash for food purchases in times of need (Otte et al. 2012).

Increasing consumption of livestock products may thus have negative outcomes for part of the population and positive outcomes for others. However, increases may occur from a low base and how products are prepared and consumed are also important determinants for health.

The nutrition transition in Central Asia

Box 5 presents key nutritional indicators relevant to the SDGs and Table 4 presents data for some of these indicators for Central Asian republics. The figures show, depending on country, a mixed pattern of undernutrition, micronutrient deficiencies and over-nutrition.

Box 5. Definitions of nutritional indicators

FAO (2019) defines the following key nutritional indicators which are also used to measure progress towards SDG goal 2 (see Annex):

Prevalence of undernourishment (PoU) (indicator 2.1.1) estimates are derived from national food balance sheet data and are computed based on three parameters: average national dietary energy supply, minimum dietary energy requirements for an average individual, and a measure of the distribution of food within a country.

Food Insecurity Experience Scale (FIES) measures food insecurity based on people's direct responses to questions regarding their access to food of adequate quality and quantity. Thus, it is an experience-based indicator that captures the access dimension of food security. FIES is measured along a continuous scale. Mild food insecurity is a worry or uncertainty about the ability to obtain food. Moderate insecurity implies that quality and variety of foodstuffs are compromised; quantities may be reduced or meals skipped. Severe food insecurity is associated with hunger. SDG indictor 2.1.2 is the proportion of the population experiencing *moderate or severe* food insecurity.

Prevalence of stunting (height for age <-2 standard deviation from the median of the World Health Organization (WHO) Child Growth Standards) among children under 5 years of age (indicator 2.2.1).

Prevalence of wasting (weight for height <-2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age (indicator 2.2.2).

Child overweight (weight for height >+2 standard deviation from the median of the WHO Child Growth Standards) among children under 5 years of age (indicator 2.2.2).

Table 4. Key nutritional status indicators in Central Asia

	PoU*	FIES (severe)	FIES* (moderate & severe)	Stunting*	Wasting*	Children overweight*	Low birth weight	Anaemia	Adult obesity	Exclusive breastfeeding
Kazakhstan	<2.5	1.9	9.3	8	3.1	9.3	5.4	30.7	21.3	-
Kyrgyzstan	7.1	5.1	23.9	12.9	2.8	7.0	5.5	36.2	15.	40.9
Tajikistan	33.2**	9.6	29.6	17.5	5.6	3.3	5.6	30.5	12.6	35.8
Turkmenistan	5.4	-	-	11.5	4.2	5.9	4.9	32.6	17.5	58.3
Uzbekistan	6.3	-	-	-	-	-	5.3	36.2	15.3	-
World	10.9			22	7.3	5.9			13.2	

Source: FAO (2019) and ** FAO (2017). *SDG indicators. PoU = Prevalence of Undernutrition; FIES = Food Insecurity Experience Scale. For definitions see Box 5.

Undernutrition is still a significant problem in Kyrgyzstan and Uzbekistan, and remains particularly severe in Tajikistan (FAO 2017). Here, prevalence of undernourishment (PoU, Box 5) is still extremely high and 30% of the population experience difficulty feeding themselves. It is the only country in the region in which physical access to food (measured by dietary energy supply, DES) is consistently below 100% compared to average requirements (FAO 2017).

In the other republics, PoU dropped sharply between the 2004-2006 and 2010-2012 periods in Kyrgyzstan, Kazakhstan and Uzbekistan. However, it has since stagnated or even started to rise again in Kyrgyzstan and Uzbekistan. In Turkmenistan, it has been rising since 2006. The prevalence of moderate or severe food insecurity as measured by FIES has also increased in the region as a whole since 2014 (FAO 2019).

Deficiencies in iron, vitamin A and zinc are still higher in Central Asia than in wealthier parts of the Europe and Central Asia (ECA) region, although reductions in iron deficiency have been achieved through food fortification (FAO 2017). These deficiency indicators exhibit clear negative relationships with income across the ECA region, particularly for iron, but for the other nutrients there is much unexplained variability, perhaps partially explained by feeding practises for young children (FAO 2017).

At the same time, overnutrition has been rising. In 2014-16 the prevalence of adult and child obesity was higher than world averages for all republics except Tajikistan, and has increased since 2010 for all five republics (Table 4). As would be expected, obesity is highest in the richest republic – Kazakhstan – but growth rates are higher in the other republics, consistent with predictions of the nutrition transition (FAO 2019). Across the ECA region, as expected from Popkin's model, the proportion of calories from sweeteners, vegetable oils and animal products increases with income, while that derived from cereals declines (FAO 2017).

Overall, we find that the three burdens: undernutrition, micronutrient deficiency and overnutrition are all present to different extents in Central Asia. Capacci et al. (2013) used indicators of these three burdens to classify ECA region countries into nutritional categories. For Central Asia they classify all countries except Kazakhstan into a group characterised by *persistent undernutrition and micro-nutrient deficiencies, and relatively low overnutrition issues*. Kazakhstan is placed in the category of countries with a triple burden - where *undernutrition persists with major prevalence of micronutrient deficiencies and higher levels of overnutrition*.

Since the 2000s, Central Asia has made important gains in reducing undernutrition and micronutrient deficiency, but these gains are extremely vulnerable, in particular because households spend a high proportion of their incomes on food (Peyrouse 2013). One source of vulnerability is dependence on remittances, which make up 48% and 31% of Tajikistan's and Kyrgyzstan's GDP respectively (Swinnen 2020). About 40% of households in Tajikistan have at least one family member working abroad (usually in Russia) and remittances are used mainly to support consumption (Akramov et al. 2020). Central Asia's dependence on wheat, in which only Kazakhstan is self sufficient, makes it highly vulnerable to food price increases (Peyrouse 2013). Both remittances and food prices were strongly affected after the financial crisis, and around 60% of Tajik households were said to have reduced their food consumption at this time (ibid.). COVID-19 is causing similar impacts, in particular a reduction in remittances; pressure on incomes may lead to decreases consumption of livestock products (Holzhacker 2020, Swinnen 2020).

Intake of animal products in Central Asia

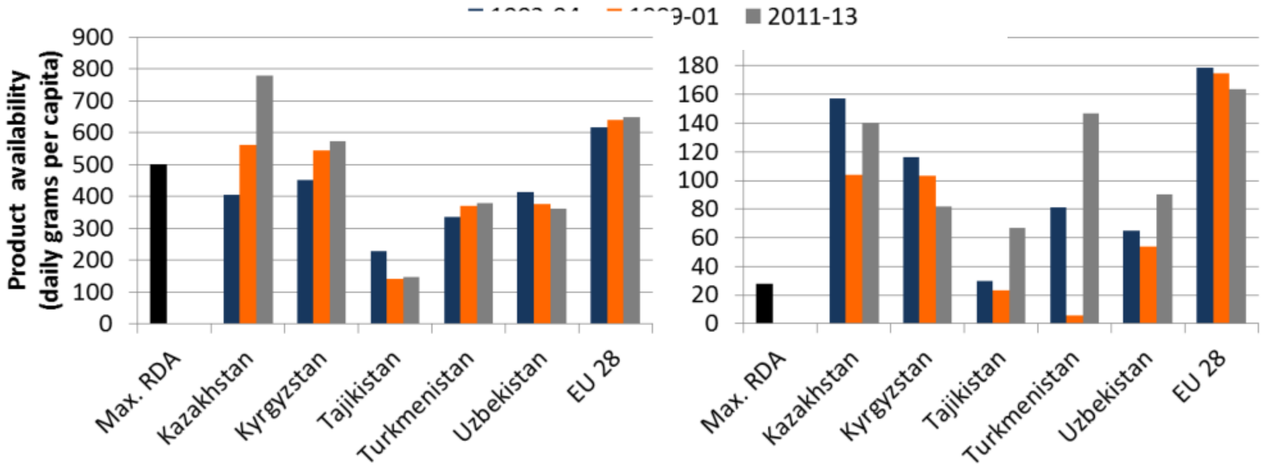
As would be expected from the above observations, dietary energy supply from animal-based foods is increasing, with estimates of mean positive change in dietary energy from animal products of 62 kcal/capita/day between 1992-1994 and 2011-2013 (FAO 2019). Increases in vegetable oil and sugar consumption are also large, although smaller than in other parts of the CIS (FAO 2019). Data in FAO (2017) show clear relationships between animal protein supply and GDP per capita both within and between low and middle-income ECA countries including Central Asian states, and similar patterns are confirmed for vegetable oils and sugar.

Figure 14 presents livestock product availability per capita for Central Asian republics. Despite the perception that countries like Kazakhstan are high meat consumers, per capita meat availability is still lower than that of Western Europe. Red meat availability in 2011–13 exceeded recommended daily amounts in all five republics, whilst availability of poultry meat remained well below recommended levels. Concerning dairy products, availability in Tajikistan falls well below recommended daily intake (the equivalent of one glass of milk per day), suggesting that livestock could make an increased contribution there.

Food availability figures do not capture real household consumption, much less its variability, and food consumption surveys are important to fill this gap. Regular food consumption surveys do exist in Central Asia (for example UNICEF et al. (2016)) but studies looking at links between livestock ownership, diet and nutritional outcomes are rarer. One such study in Kazakhstan found that the vast majority of rural households were almost completely dependent on their own household production for animal-source foods (Dalsin 2002a), but did not find relationships between frequency of meat consumption and positive health outcomes such as anaemia prevalence (Dalsin 2002b). At a broader scale, an interesting question not addressed in Central Asia is that of the impact of commercialisation in the livestock sector on prices and access to livestock products (Narrod et al. 2010).

Figure 14. Livestock product availability in average daily grams per capita

(a) Milk *(b) Red meat*



Source: FAO (2019) ; RDA = Recommended daily amount, taken from various sources used in the FAO report.

Health outcomes of dietary change

Across the region, overnutrition is evident in Central Asia's incidence of cardiovascular diseases, including high blood pressure and heart disease, which are now the number one causes of death (Aringazina et al. 2018). According to Roth et al. (2017) Central Asia has the highest incidence of age-standardised cardiovascular disease incidence in the world. Mortality rates have decreased over the past decade (except in Kyrgyzstan) but overall disease levels remain much higher than expected given the socio-demographic index used by the authors to compare mortality rates over countries at different stages of the nutrition transition.[20] The relative health outcomes associated with the nutritional profiles of Central Asian republics identified by Capacci et al. (2013), referred to above, were measured by these authors in lost DALYs (Disability Adjusted Life Years). Results suggest that countries with a triple burden (i.e. Kazakhstan) suffer a greater overall loss of DALYs than those in the '*persisting undernutrition*' category (the other republics).

It is difficult to demonstrate links between NCDs and intake of livestock products. Much of the risk of cardio-vascular disease is more likely to be related to salt intake, alcohol and smoking (Aringazina et al. 2018). The biggest contributors to loss of DALYs in triple burden countries such as Kazakhstan are alcohol, smoking and high blood pressure, although dietary risk factors and high BMI are also significant contributors (Capacci et al. 2013). Very high levels of salt and trans-fatty acids have been found in street food in cities, with some local fast foods such as *samsa* and *manty* having far over the recommended daily intake in a single serving (WHO 2017a, b). Whilst the meat in these snacks contains such fats, the type and quantity of oils used in the cooking is probably more important. As mentioned above, processed meats have a much greater health impact than unprocessed red meat (Springmann et al. 2018). However, it is also

[20] This is probably because Central Asian countries score very highly in certain indicators such as education, which give them a much higher socio-demographic index score than per capita incomes or dietary behaviour would suggest.

true that domestic meat markets, especially for mutton, favour meat with a very high fat content compared with similar products in western countries (Tilekeyev et al. 2016).

Concerning the role of trade and FDI in diets, many of the most unhealthy street foods recorded in Kyrgyzstan and Tajikistan (WHO 2017a, b) are traditional dishes, neither imported nor produced by multinational companies. Likewise, a number of common drinks are industrial versions of traditional beverages produced by local firms. However, numerous other processed snacks also exist and the type and quantity of oils used in the cooking is a big determinant of trans fatty acid content.

Major insights under Topic 6

1. *Undernutrition and food insecurity are still significant in Central Asia.* This issue is particularly severe in Tajikistan and some indicators of food insecurity have increased in recent years although childhood malnutrition has improved. Possible links between livestock sector development, prices of livestock products and access to livestock products have not been studied in the region.
2. *As incomes rise, Central Asian republics will experience a triple nutritional burden, as persistent undernutrition and micronutrient deficiencies are accompanied by rising overnutrition.* The region has the highest prevalence of cardiovascular disease in the world. Prevalence of this and other NCDs is likely to worsen as poorer areas develop, but may improve in wealthier parts of the region through education and lifestyle change.
3. *Consumption of livestock products clearly increases with wealth but relationships with nutritional status and disease are poorly studied.* Amongst very low income households access to livestock products may be associated with positive health outcomes, whilst we might expect the relationship to switch at higher incomes. But the rising burden of NCDs is also due to non-dietary factors such as smoking and alcohol. Within dietary factors, cardiovascular disease may be as related to increases in salt and trans-fats from vegetable oils as to an increase in intake of livestock products. As there are also large differences in health risk between different types of livestock products (particularly processed and non-processed), quantification of the significance of increasing meat and dairy intake on disease burden requires detailed information about consumption patterns.
4. *The nutritional status of Central Asian populations is vulnerable to shocks.* Dependence on remittances and food imports, particularly of staples in most republics, make Central Asia highly vulnerable to geo-political upheavals in Russia and to commodity prices (Swinnen 2020). The nutritional status indicators presented in this report are likely to change rapidly in the face of COVID 19.

Research questions related to Topic 6

Research questions under Trade-off B. Income growth induces malnutrition.

1. *Do the increases in availability of livestock products recorded in Central Asia improve health outcomes amongst the poorer part of the population?* One of the understudied questions concerning the livestock sector is the role played by changing availability and prices of livestock products on their consumption and on health outcomes amongst the poorer section of the population (synergies between productivity growth in the livestock sector (targets 8.2 and 2.3) and health indicators under targets 2.1 & 2.2). There are two pathways to this impact: one is the contribution to health made by livestock ownership and consumption of home–produced products; the other is the contribution of markets to consumption amongst poor non-livestock owners in terms of product availability, quality and price on health outcomes.

2. *What are the trade-offs between the economic development of the livestock sector and health (in terms of overnutrition and associated disease burden)?* A combination of economic growth and employment (targets 8.1 & 8.5) and improvements in livestock sector productivity (2.3 & 2.4) may lead to increased consumption of livestock products, with impacts on obesity (indicator under target 2.2) and associated health problems. However, there are large differences in the health implications of different types of product, level of processing and type of preparation. Locally produced livestock products such as horse sausage and industrial versions of traditional dairy products such as *kumis*, *airan* and *chakka* are increasingly found in supermarkets alongside imported products. The profile of the types of meat and dairy products which constitute changing rural and urban diets (locally produced or imported, processed or fresh) should be examined, and health impacts imputed from what is already known about the contribution of such foods to disease burdens.

Research questions under Trade-off D. More nutritious diets from livestock products overexploit feeding resources.

3. *What are the impacts of increased demand for high quality livestock products on production methods and their environmental consequences?* The results of the nutrition transition on producers themselves have been little explored in the region. These impacts may be studied by comparing production systems (targets 2.3, 2.4) and environmental footprints (e.g. targets 6.3, 6.4, 15.3, 13.2) of livestock producers supplying formal and informal value chains of the types described in Topic 5.

Topic 7. Livestock production and climate change

The livestock sector is an important contributor to global GHG emissions and in this chapter we focus mainly on climate change mitigation. However, we also describe climatic predictions for Central Asia, likely effects on the livestock sector and provide a brief survey of the major issues around adaptation.

Contribution of the livestock sector to global GHG emissions

As discussed in Topic 3, the livestock sector is responsible for around 15% of all anthropogenic GHG emissions, of which 40% is methane from enteric fermentation and 26% nitrous oxide and methane from manure deposition, application and storage (Gerber et al. 2013). But emissions from fermentation vary depending on animal age, weight and the type of feed consumed (Steinfeld et al. 2006). Methane emissions from animals fed on crop-based feed sources are 59% lower (per calorie of ASF) than those from animals fed on grass and cultivated forages (Davis et al. 2015). Taking beef systems alone (and using kg of product rather than calories), Gerber et al. (2013) found that grazed beef has double the emission intensity of beef in intensive mixed systems, whilst emissions from specialized beef herds are almost four times greater than those of beef produced from dairy herds (because emissions from dairy herds are attributed to both milk products and meat, reducing the GHG burden per unit weight of product).

Mitigation in the livestock sector

Improved feeding and husbandry

Systems with the highest GHG emissions are also characterised by low feed conversion efficiencies, poorer animal husbandry and low slaughter weights (de Vries et al. 2015, Gerber et al. 2013). However, grazing systems are highly variable; emissions can be significantly reduced by including more digestible species such as legumes in the roughage mix, pelleting and increased use of silage (Gurian-Sherman 2011) and by optimising age at slaughter, as younger and more productive animals convert feed into livestock products more efficiently than older or less productive animals (ADB 2014). In particular, feeding and housing in winter can make major contributions to livestock productivity, increasing weight gain for lambs and calves and eliminating winter adult weight loss which lowers feed conversion efficiency and delays the reaching of sale weight (ADB 2014, Gerber et al. 2013, Wilkes and Merger 2014).

Carbon sequestration

It has been suggested that the world's grasslands have significant potential to sequester carbon through improved grazing management and conversion from arable to grazing lands (Steinfeld et al. 2006), perhaps providing livestock producers with access to international carbon finance (Lal 2010, Shaumarov and Birner 2013, Tennigkeit and Wilkes 2011).

Carbon can be sequestered on rangelands because when grazing animals consume the vegetation at a rate in balance with the plants' growth rate, then these will fix more carbon from the atmosphere. Effects are largest when animal grazing results in the stimulation of root growth, in which case carbon is converted into stable forms which remain underground for long periods.

Grazing disturbance should be enough to stimulate plant growth, but not so much as to overwhelm it, which may be achieved through optimising stocking rates or managing timing of offtake through rotations (Garnett et al. 2017).

However, not all plants respond to grazing by increasing their root growth. Moreover, carbon fixation depends on availability of nutrients such as nitrogen or phosphorus. These may come via livestock themselves, through manure and urine deposition, or additional nitrogen may be applied in the form of minerals or planted legumes. But these nitrogen sources may all increase the flux of N_2O, a GHG with a per-weight impact 300 times greater than that of CO_2. The complexity involved in promoting sequestration should not be underestimated. Henderson et al. (2015) found that addition of fertilizers may lead to carbon loss as plants allocate growth into their shoots rather than roots, or because the nitrogen accelerated carbon decomposition. Levy et al. (2007) have shown that in Europe, most grassland areas are net sources for GHGs because the emissions of N_2O from soils and CH_4 from livestock outweigh the beneficial effect of sequestering carbon in soils. Even where livestock production is absent, global warming may accelerate carbon loss from grasslands, as found in the Ecuadorian páramo (Carrillo-Rojas et al. 2019).

Fundamentally, livestock add neither new carbon nor nitrogen into the system, they simply contribute to its accumulation in different ecosystem components: soils, plants or animal biomass (Garnett et al. 2017). Jones (2010) stresses that the capacity of soils to sequester carbon is finite. When a change in management or climate stimulates the process of sequestration then this process will continue until a new equilibrium is achieved at which point the carbon input is equal to that released by the mineralization of organic matter.

But, whilst gains from improved grazing management may be unpredictable, conversion of cropland to grazing land has high and relatively uncontroversial impacts on sequestration (Garnett et al. 2017). Most soils lose one-third to two-thirds of their soil organic carbon (SOC) pool upon conversion from natural to agricultural ecosystems because carbon inputs are lower than the losses due to mineralization, erosion and leaching (Lal 2004). Grasslands store more carbon than arable soils because a greater part of the organic matter is physically and chemically stabilized (Soussana et al., 2004). Thus, conversion back to grazing land can sequester significant amounts of carbon. But the gains are still time-limited. McLauchlan, Hobbie and Post (2006) have shown that former agricultural lands of the American Great Plains accumulated SOC linearly for at least the first 40 years after abandonment. However, carbon accumulation does not continue beyond about 75 years from the cessation of agriculture (Jones 2010).

In the following sections we present predictions for climate change in Central Asia, providing a brief survey of adaptation and its links with other SDGs, followed by a more in-depth focus on trade-offs between livestock production and GHG emissions and how these might follow various paths depending on future changes in production systems.

Climate change in Central Asia: predictions and adaptation

Predicted effects of climate change on agriculture in Central Asia are summarised in Box 6. All the Central Asian states have developed national climate change action plans in response to these threats, but observations by Lioubimtseva and Henebry (2009) suggest that these plans are a long way from taking a nexus approach to the problem: "The *focus of all recent national vulnerability and adaptation assessments is typically limited to sector-specific responses to the biophysical dimension of climate change. Scant attention is paid to the socio-economic aspects* *of vulnerability. Factors such as social inequality, uneven access to health care and education, rural poverty, crisis in the land tenure system, and ethnic conflicts are usually not considered by the national and local decision makers as aspects of human vulnerability to climate change. The National Action Plans of the Central Asia States hardly mention the connections between economic development, social welfare, and vulnerability to climate change and there is little consideration of multiple connections and feedback."*

This implies that the costs of climate change itself, and of adaptation and mitigation measures, have not been considered in a holistic way. An SDG nexus approach, looking at multi-sectoral trade-offs may facilitate comparison of different policy options.

Box 6. Climate change predictions for Central Asia

Temperature increases are predicted with comparatively high certainty across the region (Lioubimtseva and Henebry 2009, Reyer et al. 2017) and are likely to be higher than the global mean increase (Turco et al. 2015). Warming is likely to be particularly strong in summer and autumn, contributing to increased aridity. The extent and direction of precipitation change is subject to lower levels of certainty but decreases appear more likely in the southwest and increases in the northeast of the region, particularly in winter (Reyer et al. 2017). Therefore, cereal production in northern and eastern Kazakhstan may benefit from a longer growing season, warmer winters and slight increase in winter precipitation (ibid.), although as described under Topic 2, NDVI studies indicate current strong browning trends. Areas likely to experience worsening conditions include western Kazakhstan, Turkmenistan and Uzbekistan, where rainfall may drop, particularly with a warming of 4°C and above (ibid.). Meteorological droughts are expected to be more frequent, negatively affecting cotton production and increasing water demands for irrigation. The probability of an increase in extreme precipitation events, with associated soil erosion, landslides and avalanches, is uncertain, but seems most likely in the north of the region (Kattsov et al. 2008). Climate change impacts on ice melt and river flows are highly probable, with earlier peak flows and increased water stress in the summer. Eventually, total runoff will decrease considerably, with adverse economic effects on irrigated areas. Reyer et al. (2017) predict negative impacts on the livestock sector through decreasing pasture productivity. But at a finer scale, predictions for the sector in Kyrgyzstan find that in some locations (mostly at altitude), warmer winters and a longer growing season may favour forage availability, whilst in others heat stress and extreme rainfall events are likely to be deleterious (IFAD 2013).

A comprehensive assessment of adaptation plans from an SDG perspective is beyond the scope of this report. Recommendations on climate and livestock production in Kyrgyzstan include many measures commonly promoted by livestock sector development reports and projects that are unrelated to climate change (IFAD 2013). These include implementation of early warning systems; hazard preparation through drainage and soil protection; improvement of infrastructure and services in remote pastures; promotion of watershed management; improvement of livestock water supply systems; silvopastoral systems for improving soil humidity and shade; and increasing fodder supply through seed production, storage systems, market promotion and improved irrigation. All these actions have multiple synergies with SDGs for environment and sustainable agriculture. At the regional level, the already thorny question of cross-boundary water management will become even more important under climate change scenarios (IPCC 2014).

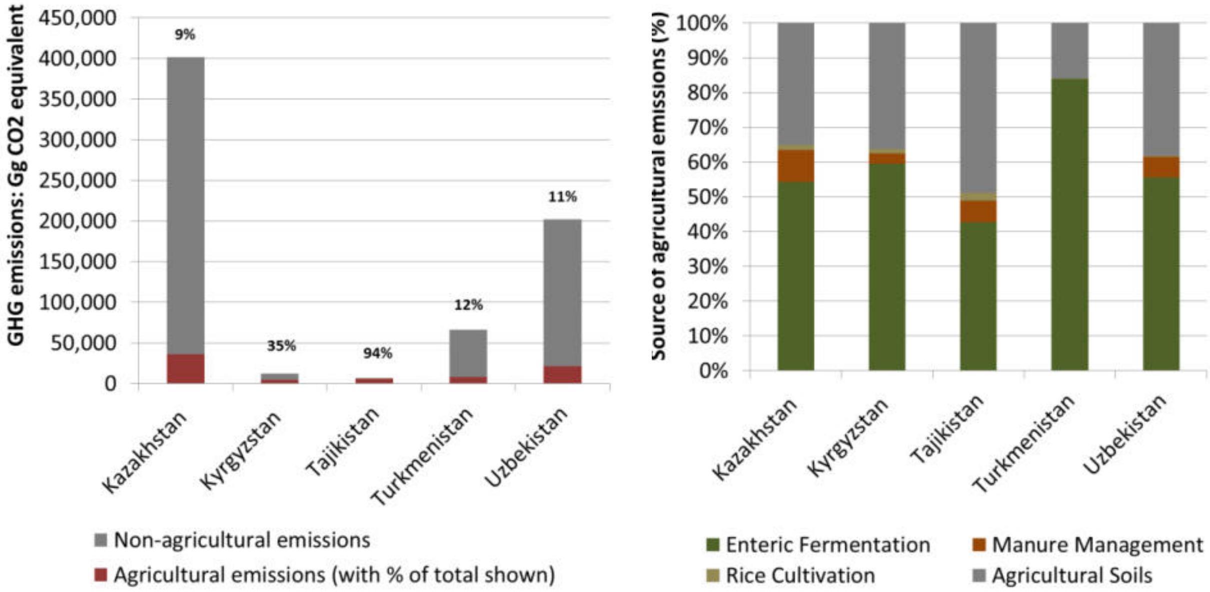
Much of the discussion on pasture management under Topic 2, in particular flexibility of movement, is relevant to livestock sector adaptation. For example in Turkmenistan, which already has the highest coefficient of variation of rainfall in Central Asia, the loosely governed and flexible access to grazing areas described in Behnke et al. (2005 & 2016) facilitates adaptation to change as it allows grazing pressure to match vegetation and water resources. However, as part of its climate change strategy, the country plans to introduce forms of individualised pasture tenure (Robinson et al. 2018) which could well have the unintended effect of reducing resilience to change. More broadly, the need for flexible tenure systems to respond to inter-annual and longer term climatic changes has been emphasised in much of the global literature on pastoralism (Fernandez-Gimenez 2002) but these ideas have had difficulty penetrating the policy sphere in Central Asia (Robinson et al. 2017).

Climate variability and risk may also affect individual behaviour in unpredictable ways. It has been shown that where such risk is higher, Kyrgyz farmers tend to shift from crop production to herding (Zhumanova et al. 2016). The logic of this can also be observed at the national level in the contribution of livestock production to Kazakhstan's gross agricultural product, which is far more predictable than that of crop production, much of which is rainfed and vulnerable to precipitation variability (Broka et al. 2016b). Little research on the response to climatic risk by farmers and livestock producers has been conducted.

GHG emissions from Central Asian states

Emissions statistics (Figure 15) demonstrate that Kazakhstan is by far the region's highest GHG emitter, with agriculture the second largest source of GHGs after the energy sector. In its Intended Nationally Determined Contribution under the Paris Agreement, Kazakhstan has set an economy-wide target to reduce emissions to 15% below 1990 levels by 2030 (Climate Action Tracker 2019). In all republics, emissions from enteric fermentation and manure management constitute over 50% of agricultural emissions. In Tajikistan these sources make up almost 50% of *all* emissions as agriculture is the major source of GHGs in that republic.

Figure 15. Greenhouse gas emissions in Central Asia
(a) Total emissions per country and proportion from the agricultural sector
(b) Breakdown of agricultural emissions by source.



Source: Authors based on United Nations Climate Change Secretariat (2020)

Potential for GHG mitigation in the Central Asia livestock sector

Feeding and husbandry

Mitigation actions suggested for Central Asian republics include improved management of the reproductive herd by optimising the average age of cattle at slaughter; improved feeding - in particular expansion of the proportion of animals finished in feedlots; and better manure management to reduce nitrous oxide emissions (Wilkes and Merger 2014, World Bank 2019). Wilkes and Merger (2014) estimated that if the proportion of Kyrgyz cattle finished in feedlots was increased from 9% (authors' estimate of current proportion) to 20%, GHG emission reductions through early offtake and improved feed would be about 54,000 tCO_2e per year.[21]

But as noted in Topic 3, the use of concentrate feed has an opportunity cost as it is dependent on use of land which could be more efficiently used for crops for direct human consumption (Van Zanten et al. 2016). From the point of view of food security, extensive systems may be desirable despite their low FCEs and higher GHG emissions. Moreover, in much of Central Asia pasturelands cannot be used for crop production and are not the result of the conversion of more carbon-rich ecosystems such as forests (another major source of livestock GHG emissions worldwide). As discussed in Topic 2, on marginal lands where arable agriculture is possible but risky, extensive grazing is more compatible with biodiversity conservation than land conversion to crops (Kamp et al. 2015).

Carbon sequestration

Schierhorn et al. (2019) found that since the end of the Soviet Union there has been a large regional reduction in GHG emissions, much of which is due to sequestration from abandonment of croplands and reduction of livestock across areas including northern Kazakhstan. These soils still hold much carbon fixation potential, as Causarano et al. (2011) found that the abandoned croplands hold around 60 t ha^{-1} SOC whilst native grasslands over 80 t ha^{-1}, a gap which would be expected to close over the next decades.

As presented in the introduction to this topic, the idea that large scale carbon sequestration can be achieved through improved grazing management assumes that the bulk of current grazing lands are very poorly managed and thus losing carbon. However, as noted in the section on land degradation in Topic 2, whilst some pastures are certainly being degraded, others are not. Where grazing is moderate, SOC may already be at equilibrium; whilst higher temperatures are more likely to trigger future carbon losses. For this reason, estimates that Central Asian soils could sequester around 16 Tg Cy^{-1} over about 50 years may be too large as they assume that the entirety of Central Asia's total rangeland area could be turned into a carbon sink (Lal 2004, Sommer and Pauw 2011).[22] Whilst large areas of abandoned cropland certainly contribute to this figure, region-wide an unknown area of grassland has been converted to cropland, which would subtract from it (see Topic 2).

Land conversion aside, Jones (2010) suggest that opportunities for increasing carbon sequestration in temperate grasslands include: (i) moderately intensifying nutrient-poor temperate

[21]Assumptions include current slaughter age of cattle of 5-6 years old (common in many developing countries), but farm surveys in Kyrgyzstan suggest that animals are slaughtered at a much younger age (Abdurasulova 2017).

[22]This is equivalent to 15.5% of the 2004 annual anthropogenic carbon emissions of the region, but described as a highly unlikely scenario by Sommer and Pauw (2011).

grasslands; (ii) reducing N-fertilizer inputs in intensively managed grasslands; (iii) lengthening the duration of grass leys; and converting low-diversity grasslands to high-diversity mixed grass-legume swards. Such interventions may be economically possible on highly productive mesic pastures, but not on vast areas of arid rangeland.

Would Central Asian countries ever be able to use improved pasture management to trade carbon credits? Commodification of carbon on rangelands implies the measurement of the rate of sequestration in soil and biomass with reference to a baseline scenario and evaluating residence time of carbon sequestered in relation to the recommended land use and risks of soil degradation (Lal 2010). Moreover, the market price of terrestrial carbon in relation to the value of the ecosystem services it provides must be determined; and a market established through the Kyoto Protocol clean development mechanism (ibid.). All of these steps are problematic. Little is known about the rate and turnover time of the below-ground carbon pool (Lal 2010). Direct measurement of SOC is expensive and requires sampling at high density due to spatial heterogeneity (Tennigkeit and Wilkes 2011), whilst existing long-term datasets on SOC dynamics and land management changes are insufficient for robust predictions (Jones 2010). The other steps necessary for establishment of a carbon market for rangelands are even more remote.

Major insights under Topic 7

1. *Given a high degree of uncertainty in predictions, climate change scenarios for agriculture in Central Asia emphasise rising temperatures and ensuing drought risk especially in the southern parts of the region.* At the same time, milder winters and higher precipitation may increase the yield potential of the northern agricultural regions. In the south, pastureland may degrade further, while livestock may be prone to more heat stress and increased competition for drinking water.
2. *Livestock systems are important GHG emitters globally. Enteric fermentation is the largest source, with a negative relationship between forage and feed quality and emissions.* Systems with the highest GHG emissions are also characterised by low feed conversion efficiency and poor animal performance, so there are synergies between intensification and emissions reduction.
3. *In Central Asia between 50% and 80% of agricultural emissions are from livestock, the vast majority from enteric fermentation associated with extensive systems and poor feeding.*
4. *Carbon sequestration on rangelands is unlikely to be a solution to GHG emissions from the livestock sector.* The contribution of livestock to SOC sequestration is small, time-limited, and outweighed by the emissions they generate. Gains in Central Asia are likely to be modest because sequestration depends on conversion of pastures from sources to sinks. Many pastures may be at carbon equilibrium already, having little potential to sequester additional carbon, others may be carbon sources for reasons unrelated to grazing management. The lack of data on carbon cycles in rangelands means that it is very difficult to identify which pastures have real sequestration potential.
5. *Land conversion between arable and pastureland is a powerful driver of carbon sequestration and loss.* Abandoned croplands in Kazakhstan will continue to sequester carbon for many years to come if they are left to regenerate towards native steppe biomes. At

the same time, in other parts of Central Asia, pasture areas have been converted to cropland, but little is known about the scale and drivers of this process.

6. *SDG synergies are most likely to be generated through better feeding and herd management as these support both climate action goals, and those linked to improved productivity and commercialisation*. One area where synergies may be found is in the development of feedlots for short term finishing, which could have positive implications for value chains, efficiency of beef production and carbon footprints.

Research questions related to Topic 7

Research questions under Trade-off C. More productive small livestock producers degrade environmental resources and Trade-off E Economic growth compromises production resources in agriculture.

1. *How do GHG emissions of different livestock production systems compare in Central Asia?* Like question 5 under Topic 3, such a question would look along dimensions of commercialisation, scale and intensification to examine the emissions associated with different types of livestock production system and look more broadly at the economic-environmental trade-offs associated with each?*
2. *Could increased vertical coordination in beef value chains (for example a feedlot stage) create synergies between emissions reduction, technical efficiency, animal productivity, reduced degradation and improved smallholder incomes?* Such a model of sustainable intensification (implying synergies between targets 2.3, 2.4, 13.2 and 15.3) could take into account the Central Asian preference for large scale farms involving hired labour. But what are the synergies with value chain integration for producers (market access aspects of target 2.3), efficiency of livestock production and processing (2.3, 8.2) and broader economic growth, innovation and employment (8.1, 8.2, 8.5)?**
3. *How significant is conversion of pastureland to rainfed cropland and what are the economic-environment trade-offs of this process?* Conversion may improve short term food security or incomes for farmers (target 2.3), but incur trade-offs in soil erosion and carbon loss (13.2, 15.3), and longer term economic losses in the livestock sector (targets 2.3, 2.4). But there is little information on how important this process has been since the 1990s, or on the implications for soil erosion and GHG emissions.
4. *What adaptation strategies to climatic variability already exist amongst livestock producers*? What synergies does increased resilience (target 13.1) have with SDGs relating to improved and sustainable productivity (2.3 & 2.4), land and biodiversity (15.3 & 15.5), and how can they be promoted?

*See Nieto et al. (2018) for similar studies in South America.
**See studies by Wilkes and Merger (2014), Abdurasulova (2017), and discussion in Topic 5.

Topic 8. Services and policies for agriculture

Agricultural incentives and implications for SDGs

Government policies and service provision are important for many dimensions of the sustainable development goals. Investment in agriculture and availability of financial services have their own targets and indicators under SDG 8 on economic growth. Outcomes in terms of access to rural services, infrastructure and finance are indicators under SDG 9 on industry, innovation and infrastructure. Government support in the form of subsidies can distort trade and domestic food prices, and targets are listed for the elimination of export subsidies and food price anomalies under SDG 2 (zero hunger). These services and policies may also indirectly support the achievement of zero hunger, poverty reduction and economic growth, through provision of finance, knowledge and infrastructure.

Policies favouring producers include various types of subsidy, market support (for example tariffs on competitive agricultural products) and services and infrastructure provision for the sector. But some of these can distort markets, leading to inefficiencies, loss of international competitiveness and high consumer prices (Anderson et al. 2008). Variable input subsidies are the most distortive, followed by output subsidies, market price support and area payments (Anderson and Swinnen 2008). Subsidy transfers, rather then benefitting a broad range of farmers, may be linked to increases in factor prices, or allocated to a small subset of farmers. Provision of services are the least distorting as they benefit the sector overall without directly affecting consumer prices. Conversely, some policies are punitive for producers, such as export tariffs and fixing of output prices to below-international levels. Other factors such as poor infrastructure, corruption and exchange rate changes can also affect producer prices and their ability to export, although these may not always be direct consequences of government policy (Anderson and Swinnen 2008).

Thus, different models of support to the agricultural sector are subject to a range of trade-offs. Policies may favour producers, with positive results for rural incomes and food security, or they may favour consumers, rendering livestock products more affordable. Governments may spend on public goods such as transport and irrigation infrastructure, research and extension and food safety or veterinary services. Or they may prioritise tax breaks and subsidies for farmers, which can be categorised as private goods (López and Galinato 2007). For these authors, provision of subsidised services such as credit may be considered as a public good if they offset market failures, or a private good if is used primarily by better-off producers who could perhaps have obtained credit on the market (ibid.).

It has been shown that spending on private goods to the detriment of public goods can have a negative impact on rural per capita income. Subsidies to private goods often fail to promote investment, employment, and productivity and may even be counterproductive to these goals (López and Galinato 2007, World Bank 2000). This makes government spending choices an important area to look at in terms of SDG research. These questions are perhaps most pertinent to Kazakhstan, which has the largest agricultural subsidy programme in Central Asia. But government investments in credit programmes, irrigation schemes, R&D and large farming enterprises are common to all republics.

Questions about the reach and effectiveness of different types of investment overlap with our discussion in Topic 1 on farm structures and Topic 5 on value chains. Although there is a temptation to channel investment into large capital intensive and vertically integrated farms such as has occurred in Kazakhstan, evidence from Western Europe suggests that large gains are possible when there are incentives for small livestock farmers to increase their size in response to market demand – through reduction in transaction costs of participating in longer supply chains (OECD 2013). For example, in the case of Kazakhstan, appropriate polices are said to include public provision of information, regulation and veterinary services, improved local infrastructure, and public provision of municipal slaughterhouses in disadvantaged regions (OECD 2013, Petrick et al. 2018).

Under this topic, we first examine provision of finance; agricultural subsidies and trade policy. Introducing published aggregate measures of distortions to agricultural incentives. We then assess how government policies in these three areas support or undermine agricultural producers and particularly the livestock sectors of each republic. Finally, we look at overall levels of public spending on agriculture and at agricultural extension systems in the region.

Land reform policies are also crucial determinants of SDG achievement. The impacts of common verses individual pasture access on different SDG were discussed under Topic 2. Barriers to land transactions perpetuate inefficiencies which emerged during restructuring and prevent farm consolidation, which is necessary for commercialisation (Lerman 2004). These issues are discussed under Topic 1.

Financial services

The World Bank Findex dataset allows comparison of access to financial services between countries (Table 5). Uzbekistan's financial sector is relatively undeveloped, with the lowest proportion of people taking formal loans in Central Asia. Micro-credit organisations (MCOs) do exist, but may demand physical collateral and have interest rates reaching over 50% (IFAD 2015). Credit unions were shut down in 2011, and re-authorised in 2020 under new legislation.[23] State banks account for about 85% of banking system assets and subsidised lending accounted for around 50% of loans in 2018, but significant administrative obstacles negatively affect demand for loans aimed at farmers (Naumov and Pugach 2019). Overall, it is not clear how much credit reaches the livestock sector but real interest rates faced by most farmers are said to be around 18-24% per annum (ibid.), which is prohibitive, whilst households tend to have poorer access to credit than individual farms (Robinson 2020).

In Kyrgyzstan, access to finance is now provided by microfinance institutions, banks, credit unions and international donors. Government support for farmers includes subsidising interest rates and lowering the tax burden. The legislative base of this financial support programme is the law "On the Development of Agriculture of the Kyrgyz Republic" (Ministry of Justice, 2009) under which a series of phased financing programmes has been introduced. The current phase (6) subsidizes commercial banks and credit organizations for loans at preferential interest rates of 10% per annum for livestock and crop production and 6% per annum for processing enterprises. Lending is supposed to prioritise business entities which are part of value chain 'clusters', with 25% of financing allocated to processing enterprises which have concluded contracts with local producers for the supply of agricultural products. Up to 50% of the

[23] For further details see https://regulation.gov.uz/ru/document/21738.

total amount of financing may be for livestock production, of which at least 10% should be directed to the purchase of pedigree cattle.

Table 5. Access to financial services in Central Asian republics and the ECA region (All figures are percentages of surveyed adults).

Country or region	Has bank account	Borrowed any money in the past year	Borrowed to start, operate, or expand a farm or business	Borrowed from a financial institution	Borrowed from family or friends
ECA	65	44	12	13	24
KAZ	59	46	21	20	22
KGZ	40	32	9	9	17
TJK	47	34	13	15	22
TKM	41	37	8	7	21
UZB	37	20	1	2	13

Source: World Bank Findex database, based on sample surveys with around 1000 adults per republic. Figures presented cover the country as a whole, but those disaggregated for rural areas alone, are very similar.

But the volume of support is limited. Phase 5 of the agricultural financing programme, issued in 2017, covered only 7.5-9 million USD of the total of 50-60 million USD of loans issued annually (O'Connell and Kiparisov 2018). A subsidised interest rate makes bank products relatively affordable, but the short maturity period (three years for phase 6) limits farmers' ability to take medium and large loans. In the livestock sector it has been observed that most loans are used to finance recurrent costs such as medicine, semen and calves for fattening, rather than on-farm investments (IFAD 2016).

Kazakhstan also provides subsidised credit lines through various support programmes. At 118 million USD, financial services made up over 50% of the total agricultural budget in 2017 (Mussayeva 2018). Bank account ownership and access to credit from a financial institution are comparable to ECA means (Table 5). But there is evidence that only a small proportion of livestock owners who would like to take credit actually apply. This reflects ineffective demand, as many farmers doubt their ability to repay loans under current market conditions (Petrick et al. 2017b, Robinson 2020). More recently Kazakhstan has been moving away from direct subsidization of credit and towards guaranteeing loans for farmers (OECD 2020).

Subsidies

Veterinary services are subsided to some extent in most Central Asian states, and vaccines are often free, although a service charge may be paid to the vet, for example in Kyrgyzstan (Broka et al. 2016a). In that republic, non-credit subsidies to agriculture have consisted over the years of short term programmes including distribution of subsidised fuel, seeds and fertilizers, machinery, and price stabilisation through crop purchases by the Agricultural and Food Corporation, established in 2008 (O'Connell and Kiparisov 2018, Zhunusova 2017). Recent initiatives include tax incentives for agricultural cooperatives, machine-tractor stations and trade and logistics centres (O'Connell and Kiparisov 2018). In Tajikistan, there are few subsidies to speak of, with most farmer support provided by international donors, but the government runs machinery leasing programmes (FAO 2018b) and heavily subsidises electricity for irrigation (Shenhav et al. 2019).

In Uzbekistan, a livestock sector programme initiated in 2006 included (i) provision of 100,000 cows for low-income families at the expense of sponsors and entrepreneurs; (ii) subsidised loans for livestock production and (iii) creation of field outlets for cotton husks and sunflower seed (Naumov and Pugach 2019). The programme also organized sale of pedigree cattle through auctions to farmers between 2006 and 2010 and expanded microcredit for households (Lerman 2008). There followed a short term increase in the number of farms specializing in livestock raising and in the overall number of livestock in farms, but this did not reverse the longer term trend of decreasing proportion of livestock in farms and enterprises compared to households. Production subsidies are given for cultivation of crops under state orders, mainly for the purchase of fuel, seeds, fertilisers and machinery services.

Kazakhstan's agricultural programme for 2017-2021 invests 2,374 billion tenge (6.1 billion USD)[24] in the sector. The bulk of this is earmarked for subsidies and credit, but 34% is for infrastructure and services (Petrick et al. 2018). Livestock programmes include payments towards purchase of pedigree livestock, support for feedlots and output subsidies for raw produce sold to processors (Government of Kazakhstan 2017). Leasing/purchase schemes covering a proportion of investment cost facilitate access to machinery. Per hectare crop input subsidies have recently been cut back but payments for pesticide and fertiliser remain and those for quality seed purchase have been significantly developed (OECD 2020). Subsidies have previously been aimed at large farms, with conditions specifying minimum herd sizes, animal weights at sale or hectares planted, but the current package puts a greater emphasis on small farms, and includes subsidies to cooperatives whose members individually would not meet the scale criteria (Government of Kazakhstan 2017, Petrick et al. 2018). Overall it is estimated that 6% of total beef production and 5% of milk production are subsidised (Ministry of Agriculture of Kazakhstan 2017). Whilst most subsidies promote intensification, funds for well and winter house rehabilitation also demonstrate a desire to bring abandoned pasture back into use (although cost coverage rates for wells has dropped from 80% to 25% (OECD 2020).

There has been very little research on the reach and impact of subsidies on welfare and farm outcomes. In Kazakhstan, it appears that, despite the new focus on cooperatives, subsidies are mainly received by the top quartile of individual farms (Robinson 2020). A study on large dairy farms and enterprises in Russia and Kazakhstan found that subsidies are positively associated with herd growth but the authors suggest that public investments in better farm management and vertical coordination would be more effective (Petrick and Götz 2019).

Trade policy

In addition to the trade agreements discussed in Topic 5, and progress in accessing new markets, some republics also protect their livestock sectors in various ways, with Uzbekistan the most protective economy and Kyrgyzstan the most liberal for trade in agrifood products (Mogilevskii and Akramov 2014).

[24] Using exchange rate from January 2020. The USD value has since decreased.

Even between CISFTA members there are some exceptions to tariff-free trading, for example export duties on livestock products for which countries would like to promote domestic processing, such as wool from Kazakhstan (Mogilevskii and Akramov 2014). Uzbekistan practises export bans, often to protect local supplies for processing industries and including live animals and meat. It also levies very high import excises on meat and dairy products including powdered milk (IFAD 2015, Mogilevskii and Akramov 2014). But the three non-EAEU republics do not apply TRQs (FAO 2018b).

Kazakhstan applies a range of border and domestic price intervention instruments through the EAEU, including TRQs and non-tariff measures (OECD 2019a). TRQs apply to imports of beef of lower grade and poultry products. A TRQ of 21,000 tonnes applies to imports of fresh, chilled or frozen beef. Bound rates for in-quota tariffs are set at 15%, and over-quota imports at 40% (OECD 2019a). Export duties cover wool, hair and more recently, skins (FAO 2018b). Sharp increases of livestock exports in 2019, combined with rises in domestic meat prices and shortages of raw products for meat processing plants led the government to announce export bans on live animals (Kazakhstan Chamber of Commerce 2020).

Perhaps more important than tariffs or export bans, there are significant technical barriers to trade (TBT) within the region, including customs administration, transport limitations and sanitary barriers. Here, all Central Asian countries, but particularly Uzbekistan, are poor performers according to international indices measuring ease of doing business across frontiers (Mogilevskii and Akramov 2014). One result of accession of countries to the EAEU has been the increase in TBT between members and non-members, for example resulting in long queues on the southern borders of Kazakhstan (ibid.).

But there have been positive developments, one of which is Uzbekistan's recent relaxation of border controls with its neighbours. This liberalisation has affected trade in agricultural products with Kazakhstan, transit of Uzbek agricultural products through Kazakhstan to Russia, resumption of flights between Tashkent and Dushanbe and operations at border checkpoints for road and rail transit (Dzardanova et al. 2018). Little information is available about the effects of these changes on trade with neighbouring countries.

Distortions to agricultural incentives and measures of consumer and producer support

Aggregate metrics used to measure distortions to agricultural incentives include those produced by the OECD and the World Bank (Anderson et al. 2008). OECD indicators are available only for Kazakhstan (Box 7) whilst the alternative Nominal Rates of Assistance (NRA) have been estimated for all republics, but are rather out of date (see discussion below).

According the OECD monitoring system of agricultural policies, the Total Support Estimate indicator (TSE) represents the total of policy transfers to the agricultural sector expressed as a share of GDP (OECD 2020). It consists of transfers to agricultural producers, consumers and support to general services to agricultural sector (GSSE) which includes agricultural research and development, training, inspection and marketing. The OECD measures the transfers to agricultural producers as the Producer Support Estimate (PSE) - the annual monetary value of gross transfers from consumers and taxpayers to agricultural producers, which can be expressed as a percentage of gross farm income (%PSE). The PSE is defined as the aggregate of Market Price Support (MPS), such as subsidised farm commodity prices, and direct transfers to producers. The Consumer Support Estimate (CSE) is an indicator of the annual monetary value of government transfers to (or from) consumers of agricultural commodities. The proportion of TSE represented by General Services Support Estimate (GSSE) is one indicator that helps to understand the extent to which governments invest in public goods as opposed to private goods.

As we can see from the discussion in Box 7, this metric is increasing in Kazakhstan. An analysis of the 2017-2021 plan for development of the agricultural sector found 53% of the projected budget to concern subsidies and 6% general services. The rest (12% credit and 27% infrastructure) could also be of general support to the agricultural sector depending on how funds are allocated. Significant commitments for irrigation, for example, may go some way to improving the fodder base (Petrick et al. 2018).

Box 7. OECD measures of producer and consumer support in Kazakhstan

Though not a formal member, Kazakhstan is the subject of agricultural policy monitoring by the OECD (e.g. OECD 2013; 2015; 2019; 2020). In Kazakhstan, the producer support estimate (PSE), (annual monetary value of gross transfers from consumers and taxpayers to agricultural producers) expressed as a percentage of gross farm income (%PSE), fluctuated considerably between 1995 and 2011 (OECD 2013, 2019). Even so, it was positive in most years, indicating overall policies protective for domestic producers. From 2016 to 2019 around 3% of gross receipts of agricultural producers could be attributed to support policies (OECD 2019a, 2020).

Most of the inter-annual variation in PSE is accounted for by fluctuations in Market Price Support (MPS). This measures the gap between domestic prices and international prices, which is the outcome of price taxation of some commodities (a negative MPS) and price support of others (a positive MPS). From 2017-2019, domestic producer prices were on average below world levels, leading to a negative aggregate price support for several crops and an implicit transfer from farmers to consumers. But MPS is positive for livestock products as meat and milk are protected through import tariffs and prices for feed grain are generally below world levels. The weakness of market infrastructure creates additional protection to producers as it increases logistical costs of importation. Budgetary transfers, which come from taxpayers are the other component of PSE, and have been rising in Kazakhstan. Overall, production distorting forms of support such as MPS and payments based on output, and on variable input use with no constraints, decreased from around 98% in the early 2000s to 61% on average in 2016-18 but stood at 69% from 2017-2019 (OECD 2019a).

Similar to the PSE, the Consumer Support Estimate (CSE) can be expressed in relative terms as a percentage of total consumption expenditures on domestically produced goods (%CSE). The average %CSE for Kazakhstan was estimated at -6% in 2008-10, indicating that policies to support agricultural prices increased consumption expenditure by 6%. This tax on consumers is relatively modest in Kazakhstan compared to other emerging economies. But consumption of livestock products is taxed more than this amount, while consumption of crop products is typically subsidised.

There has been a shift in the composition of the TSE from support to individual producers towards support to general services, as reflected in an increase of the proportion of GSSE in TSE from 12% in 1995-97 to 24% in 2017-2019. This reflects investments in services including pest and disease inspection and control and market infrastructure. However, some areas that are critical for agricultural development, such as infrastructure and education, receive relatively little support.

Similar to the PSE, the NRA (Anderson et al. 2008) is defined as the percentage share by which government policies have raised (or lowered) gross returns to producers above what these returns would have been without the government's intervention.

Attempts to calculate this indicator for agricultural commodities in Central Asian states found overall positive support to agriculture in Kazakhstan in the mid 2000s and, as noted in Box 7, this support was negative for wheat and highly positive for livestock products (Pomfret 2008b). The NRA in Kyrgyzstan was found to be broadly positive for producers, with domestic prices for major food crops much higher than world market prices (Christensen and Pomfret 2008, Zhunusova and Herrmann 2014). As many commodities are not traded it is difficult to calculate the market price support component but it appears that products for export benefit less than food crops (Zhunusova and Herrmann 2014). The governments of Tajikistan, Turkmenistan and Uzbekistan have used state marketing monopolies to transfer vast resources out of the cotton sector, reaching 50% of all gross cotton revenue of Uzbek farmers in 2000, although livestock production has been less affected (Pomfret 2008a). Uzbekistan has since begun a process of liberalisation but policies in Turkmenistan and Tajikistan have seen less real change (ibid.).

Metrics of total support are imperfect indicators of the distortions in incentives because the magnitude of effects are very different for trade, price, and subsidy instruments. Moreover, not all distorting factors are the results of policy. Tariffs aside, other types of trade barrier such as poor transport and storage infrastructure, corruption and bureaucracy effectively protect import-competing industries and tax export-oriented ones. These kinds of trade costs comprise the equivalent of an export tax on Kazakh wheat amounting to between 10 and 25% (Pomfret 2008b). In the Kyrgyz Republic, where policy induced distortions are small; these costs may account for very large gaps between domestic and international prices (Anderson and Swinnen 2008, Christensen and Pomfret 2008). Poor infrastructure is associated with the weak transmission of border prices, preventing the export of surpluses to other regions within the same country or across borders, and depressing prices in times of good harvests. Changes in exchange rates (induced by both policy manipulations and structural changes or changes in terms of trade) have also had major impacts on agricultural incentives (Anderson and Swinnen 2008).

Agricultural spending, research and extension

Spending on agriculture

SDG target 2.a is to "*increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries*."

The FAO (2019) has reviewed progress towards this goal in Europe and Central Asia.[25] In Central Asian counties, spending on agriculture in 2014-2016 was below 3% of GDP (which is considered to be low) in all cases except Uzbekistan and has declined across the region compared to the previous period of 2009-2011.

The agriculture orientation index (AOI) (SDG Indicator 2.a.1) is a ratio of two shares – the percentage of central government expenditures spent on agriculture and the share of agriculture in the total gross domestic product. So this indicator represents the extent to which spending on agriculture reflects its economic importance. An AOI greater than one indicates that investment in agriculture is lower than its share in the economy whilst an AOI below one suggests the

[25] Although there is no specific target for public spending on agriculture as a share of total government expenditures, FAO (2019) take the figure of 10% based on a target committed to by African governments in 2003 in the Maputo Declaration on Agriculture and Food Security in Africa.

opposite. In Central Asia, this metric is both below one and declining for most countries. The highest value was for Kazakhstan, where AOI had almost reached 0.9 in 2009-2011 but dropped back to below 0.5 in 2014-2016. The latest estimate for Kyrgyzstan is below 0.2. These figures indicate that chronic under-investment in agriculture is worsening in most cases (FAO 2019).

Agricultural extension services

In the Soviet period, agricultural knowledge was generated in research institutes affiliated with the Ministry of Agriculture or the Academy of Sciences, with a strong system of information exchange across the Union. Regional departments of the Ministry of Agriculture, *agroprom*, had offices at the district level which transferred knowledge and innovations to sovkhoz and kolkhoz, which themselves had their own agronomists and livestock specialists (Shtaltovna 2016).

Since the breakdown of the Soviet system, institutes have had to both re-route learning channels, and adapt to a new language of innovation (English). Many remain inadequately funded, isolated from the international scientific community, and unable to recruit and train young scientists. Locally, whilst there are still some agronomists and livestock specialists at the district level, they have only weak links to extension services, whilst research outputs are often outdated or unsuited to small scale farming (Mirzabaev et al. 2009, Shtaltovna 2016).

Various agricultural extension models have been attempted in the independent republics. In Tajikistan, as described by Shtaltovna (2016), most services are provided by NGOs (which often hire former state employees) but provision is uncoordinated, fragmented and of dubious sustainability. Some donors have tried to work through farmers associations or cooperatives but the weakness of these institutions undermines effectiveness. Farmers are rarely willing to pay for advice alone, so knowledge transfer is often tied to other services such as micro-finance or input shops, which have more viable business models. An EU-funded effort in 2007-2010 was made to coordinate donor efforts through a national extension service but this did not outlast the project (Kazbekov and Qureshi 2011).

In Kyrgyzstan, in addition to numerous NGO-provided extension services, there is a government-established national service known as RAS – Rural Advisory Services - which is essentially donor-funded and works partly as a farmer-controlled association and partly a private sector provider (Mirzabaev et al. 2009). RAS built up a network of district offices, members and permanent clients, but is said to suffer from low staff salaries, inadequate funding, constantly changing donor priorities and weak political support, which puts this national extension model at risk (Kazbekov and Qureshi 2011).

In Uzbekistan, apparently high access of farmers to extension services can be explained by government support to farmers participating in the cotton and wheat state procurement (Bobojonov et al. 2016). Although there are a number of organizations providing broader elements of extension services, such as the Association of Private Farmers and Rural Business Advisory Services, these are in fact government-established and neither completely meet the needs of farmers nor act as conduits for innovation (Kazbekov and Qureshi 2011). Networks of informal knowledge transfer between farms, and from farms to households (which often work for farmers), have been described for this republic and are likely to be important elsewhere also (Djanibekov 2016).

In several republics, water management organizations have been used as extension platforms, for example the Water Productivity Improvement Project used Basin Irrigation System Authorities in Uzbekistan provide farm field schools for selected WUAs, using demonstration fields

(Kazbekov and Qureshi 2011). In Kyrgyzstan, WUA support units, funded by the World Bank, provided capacity building on water governance and financial management, but have also been used as broader extension agents for agronomic practices, with a special focus on the efficient use of water (Johnson III and Stoutjesdijk 2008). Kyrgyz Pasture Users Associations have been used as conduits for training in natural resource management and business development under donor-funded projects.

In Kazakhstan, financial resources are rather better and salaries for scientists are higher. A government funded extension system exists under the umbrella of KazAgroInnovation, which set up six regional Extension Centres based on the presence of scientific research institutes. These centres organize field demonstrations of new technologies and equipment, and offer educational programs and seminars for farmers. The National Chamber of Entrepreneurs, to which farmers must pay mandatory membership fees, provides farmer-oriented business training to accompany credit programmes run by subsidiaries of the state-owned holding Kaz-Agro. However, anecdotal evidence suggests that seminars are rather theoretical and focus on innovations rather than support and consulting (Andirova 2014). This approach is rather different to that of advisory services in Kyrgyzstan, where extension agents visit villages on a regular basis, build up long term relationships with clients, and provide a range of services going well beyond technical advice (Kazbekov and Qureshi 2011, Schmidt 2001). Standardised technology transfer models of extension are often poorly adapted to the needs of individual farmers, whereas participatory research and technology development may be more appropriate (Schmidt 2001). Likewise, agricultural research in Kazakhstan is said to be '*neither problem- nor client-oriented*' (FAO 2011a). State Institutes provide consultancy services for the very largest farmers but there is little focus on improving production on small farms, nor is there a mechanism to deliver such innovations.

Extension in value chains

We saw in Topic 5 that processors and input suppliers may transfer technology and knowledge through contracting. There are plenty of examples in transition countries of (usually dairy) companies providing extension, even to very small farmers, on drafting business plans, feeding, hygiene and improving fertility (Berkum 2005, Dries and Noev 2005). But in Central Asia, direct provision (for example through provision of milk coolers, milk testing or husbandry advice) seems to be unusual. Milk traders may transfer information on quality demands through testing, but traders may themselves have limited relationships with firms. Cashmere, one of the most valued livestock products on global markets is a case in point. Here, information on quality-price relationships which exist on world markets are not passed on to producers by itinerant and unregulated purchasers selling on to China, which has resulted in a debasing of value throughout the Chinese part of that market, and undermined attempts by firms to provide extension services to farmers in order to obtain higher value product (Waldron et al. 2014). Kuijpers and Swinnen (2016) analysed factors affecting technology transfer by companies, finding that the surplus generated by the technology, agents' opportunity costs, opportunities for holdups, and contract enforcement institutions were all important. In Central Asia much more could be done to investigate extension models of large firms which have invested in dairy, and (even less studied), in beef production.

Concerning technology transfers between farms of different scales, it has been said that Uzbek households (*dekhans*) working for commercial farmers have improved milk yields of their own cattle at home thanks to better feeding, artificial insemination and other husbandry practices learned from their employers (IFAD 2015). In other republics, the relationships between farms of different sizes, and the role of larger enterprises have been little studied.

Industrial policy and broader economic development

Urbanisation, resource extraction and infrastructure development can all affect the resources needed for livestock production. Many of the threats to steppe and desert biodiversity in Kazakhstan reviewed by Kamp et al. (2016) also affect grazing systems. The highest-ranked of these were related to changes in land use and rapid infrastructure development. New roads in Almaty already region hamper livestock access to summer pastures, whilst rail links as part of the Belt and Road Initiative will cut across huge areas of rangeland. Conflicts between mining and livestock production, both by large companies and through artisanal extraction, have been reported in Kyrgyzstan (Mestre et al. 2013, Steimann 2011). Although new grazing areas opened up on former croplands in the 1990s, since 2000, about five million ha have been re-cultivated (Petrick et al. 2013). Emerging demand for biofuels may put pressure on land use for livestock in the future through competition with fodder crops (de Haan et al. 2010, Kamp et al. 2016).

Economic growth in other sectors of the economy can also have an indirect impact on livestock production. Income diversification in pastoral areas may support the sector as savings are often invested in livestock (Sabyrbekov 2019). The same applies to income from labour migration (Schoch et al. 2010). But some activities may be a source of conflict, for example where mountain tourism creates a high concentration of pasture users in one area (Mestre et al. 2013).

Major insights under Topic 8

1. *Distortions to agricultural incentives and the allocation of spending to private or public goods can influence agricultural incomes and consumer prices.* This makes government policy and spending choices an important area to look at in terms of SDG research.
2. *Governments in most Central Asian republics support credit interest rates but these services are most likely to be used by larger farms.* Lack of effective demand is an issue, with farm profitability too low to support repayments.
3. *Direct subsidies for inputs, investments and outputs in the livestock sector are rare outside Kazakhstan.* Here, only the largest farms can meet the conditions for these payments.
4. *Some Central Asian governments engage in protective trade policy in favour of the livestock sector,* for example through tariffs and import excise in Kazakhstan and Uzbekistan respectively. Both countries sometimes attempt to protect consumer prices and the processing industry through export bans. Uzbekistan is now liberalising, but considerable non-tariff barriers to trade remain.
5. *All Central Asian republics under-invest in agriculture compared to its economic importance.* International literature suggests that expenditure on public services such as extension and infrastructure is more likely to benefit rural incomes and food security than investments in private goods. Outside Kazakhstan little analysis has been done on this question.

6. *There is a lack of national policy frameworks for the development of agricultural extension services*, without which donor investments lack coordination and coherence. Links between international knowledge generation, national research institutes, and farmers are extremely weak.
7. *Services need to be flexible, dynamic and responsive to farmers' needs rather than formal and highly technical.* Knowledge transfer may be best combined with other services such as input provision, renting machinery services, or breeding programmes within which the costs may be subsumed. Cost effective conduits may include farmers' organisations, cooperatives, water or pasture users' associations, depending on which of these come closest to actually representing farmers in a given republic.
8. *Broader economic development can have negative effects on the livestock sector.* The failure to consider impacts of large infrastructure projects on grazing systems leads to their fragmentation, with analogous impact on both livestock and wildlife. Investments in other sectors, such as mining, may cause conflicts with livestock production.

Research questions related to Topic 8

Research questions under Trade-off A. Commercialisation excludes smallholders.

1. *Does trade and subsidy policy favour agricultural producers or consumers and what are the implications for SDG trade-offs?* Macroeconomic studies suggest that livestock products are relatively protected, but what is the impact on producers and consumers at the level of the farm and household? This question concerns SDG targets to prevent distortions in agricultural trade (2.b) and support proper functioning of domestic food commodity markets (2.c) - and their relationships with indicators relating to farmer incomes (target 2.3) and food security (2.1).
2. *What are the relative investments by governments into private and public goods in agriculture, and their impacts on key SDG indicators and trade-offs?* This concerns the nexus of SDG targets 2.a (investment in agriculture), 2.b (avoidance of trade distortion) and 2.c (food market stabilisation), and the effects of these policies on poverty, nutrition and food security (targets 1.4, 2.2 & 2.3).
3. *What are appropriate models of finance provision for livestock sector development?* Smallholders and commercial farmers are likely to have very different needs and uses for credit. To what extent do existing programmes cover these needs (target 8.10) and support growth or farm expansion and development in both farm types? Some studies have been conducted looking at credit demand and supply in various Central Asian countries, but much more could be made of existing survey data on this topic, exploring SDG outcomes in terms of farm productivity (2.3), investment and growth (8.2).
4. *What are the impacts of subsidies on rural inequality, farm profitability and intensification of livestock production?* In Kazakhstan, little research has been done on how subsidy conditionalities affect farmer decision making, or on equity effects - whether subsidy receipt increases the market share amongst recipients to the detriments of smaller farms (nexus of policies under targets 2.b & 2.c and targets 1.4 & 2.3).
5. *What has been the impact of trade liberalisation by Uzbekistan on SDG goals and have there been trade-offs for some producers?* Uzbekistan is only now liberalising trade with neighbouring states (target 2.b) but the impacts on producers and processors inside the country, and in neighbouring states has not yet been assessed.
6. *Which extension models are most likely to promote SDG goals?* Central Asian states have taken different paths to extension provision (which comes under target 2.a) and within

single countries donors, suppliers and companies have attempted a plethora of methods and approaches. Concerning livestock producers in particular, there is almost nothing written on extension needs, access, or outcomes of programmes. A structured comparative assessment of these, using SDG metrics under target 2.3 such as accessibility of knowledge, and results on farm productivity and income, should be conducted.

7. *To what extent do farmers obtain knowledge and technology from processors, suppliers and peers?* Private extension provision within value chains, and factors determining its feasibility, coverage and benefits have hardly been studied in Central Asia. This question overlaps with that listed under Topic 1 on relationships between households and farms, and questions under topic 5 on contract farming.

Research questions under **Trade-off E** Economic growth compromises production resources in agriculture.

8. *How do government agricultural polices, particularly those on trade and subsidies, impact environmental indicators, such as land degradation and water scarcity?* By changing incentives, these policies (concerning targets 2.b & 2.c) can affect farming decisions through prices of inputs and outputs, influence intensification trends and patterns of resource use (relating to targets 2.3, 2.4, 6.3, 6.4 & 15.3).

9. *How does broader economic growth affect resources needed for livestock production?* Industrialisation, urbanisation, infrastructure development and resource extraction (concerning multiple targets under SDGs 8 & 9) can all have impacts on the pasture, soil and water resources needed for livestock production (under SDGs 15 and 6).

Questions on land reform and broader sector restructuring, for example through cluster projects, are also significant areas of government policy, and are discussed under Topic 1.

A research agenda

Table 6 summarises the potential research areas outlined in the above chapters, grouping them by the different SDG trade-offs identified in the introduction. Some of the questions appeared in slightly different forms under different topics and have been merged here.

Table 6. SDG trade-offs and the livestock sector: a summary of research areas

Topic	Question
Trade-off A. Commercialisation excludes smallholders	
1	What is the evidence that farm restructuring has excluded smallholder access to value chains and thus incurred trade-offs for SDG goals?
1/3	Is the relationship between households and farms, or between small and large farms mutually beneficial?
1	How do the different types of livestock farm which emerged from restructuring compare in terms of technical efficiency?
1	How has restructuring affected individual animal performance and its determinants?
2	To what extent do smallholders benefit from improved legal access to pastures?
2	Do common property systems promote or prevent value chain commercialisation?
3	What are the extent and determinants of water supply inequality and are there economic trade-offs involved in improving irrigation water supply to smallholders?
3	How will commercialisation of beef and milk production affect livestock feeding strategies and what are the consequences for food security if scarce irrigated land is converted to fodder crops?
4	What are the trade-offs implicit in adoption of high yielding livestock breeds for different types of farm? Is it more beneficial for smallholders to close the gap between actual and potential performance of local breeds than to adopt new breeds?
4	What are the determinants of participation in breeding programmes?
5	How successful are cooperatives, private intermediaries and processors in facilitating vertical coordination in dairy value chains?
5	How prevalent are contract farming arrangements among producers in Central Asia? What are the determinants of participation, and to what extent do participating farmers benefit?
5	Is beef value chain development likely to lead to vertical coordination or vertical integration? What are the social and economic costs and benefits?
8	Does trade and subsidy policy favour livestock producers or consumers and what are the implications for SDG trade-offs?
8	What are the relative investments by governments into private and public goods in agriculture, and their impacts on key SDG indictors and trade-offs in the livestock sector?
8	What are appropriate models of finance provision for livestock sector development?

8	What are the impacts of subsidies on rural incomes, equality and farm profitability? Do they discriminate against smallholders?
8	What has been the impact of trade liberalisation by Uzbekistan on SDG goals and have there been trade-offs for some producers?
8	Which national extension models are most likely to promote SDG goals?
8	To what extent do farmers obtain knowledge and technology from processors, suppliers and peer farmers?
Trade-off B. Rising incomes cause malnutrition	
3/6	Do lower prices or increases in availability of livestock products recorded in Central Asia improve health outcomes amongst the poorer part of the population? What are the determinants of prices and what role does intensification play in product affordability?
6	What are the trade-offs between the economic development of the livestock sector and health (in terms of overnutirition and associated disease burden)?
Trade-off C. More productive small livestock producers degrade environmental resources	
2	Does improved access to pastures by smallholders incur improvements in pasture management or does it conflict with environmental goals?
2/7	How significant is conversion of pastureland to cropland by smallholders and what are the economic-environment trade-offs of this process?
3	Are improvements in water use efficiency compatible with improved access and more equitable water supply?
3	What pathways to intensification are being used by farmers in Central Asia and what are the bio-economic trade-offs involved?
3	Can synergies between fodder crop production, soil improvement and yields of other crops be realised?
7	How do GHG emissions of different livestock production systems compare in Central Asia? What are the trade-offs with other SDG goals?
7	Could increased vertical coordination in beef value chains (for example a feedlot stage) create synergies between emissions reduction, technical efficiency, animal productivity, reduced degradation and improved smallholder incomes?.
7	What adaptation strategies to climatic variability already exist amongst livestock producers? Might these also mitigate other environmental impacts of livestock production in the future?
Trade-off D. More nutritious diets from livestock products overexploit feeding resources	
6	What are the impacts of increased demand for high quality livestock products on production methods and their environmental consequences?
Trade-off E . Economic growth compromises production resources in agriculture	
2/3	How does the commercialisation of beef and milk production affect feeding strategies (intensification verses extensification), crop choices and water use? How do these changes affect pasture, soil and water resources?
4	To what extent does the import of high yielding breeds with specific husbandry requirements change farming and its impact on the environment?
8	What are the environmental trade-offs associated with trade and subsidy policies?
8	How does broader economic growth and rural income diversification affect resources needed for livestock production?

Acknowledgements

This report was written in 2020 by Sarah Robinson and Martin Petrick, Centre for International Development and Environmental Research (ZEU), Justus Liebig University Giessen, Senckenbergstrasse 3, 35390 Giessen, Germany. The work was funded by the German Academic Exchange Service (DAAD) from funds of Federal Ministry for Economic Cooperation (BMZ), SDG^{nexus} Network (grant number 57526248), programme "exceed - Hochschulexzellenz in der Entwicklungszusammenarbeit".

We gratefully acknowledge inputs and reviews from Alicia Correa-Barahona, Christoph Funk, Nozilakhon Mukhamedova, Vladimir Otrachshenko, and Ramona Teuber.

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Annex: SDG targets and indicators relevant to the livestock sector

SDG	SDG Target	SDG Indicator
1 No Poverty	1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	1.4.1 Proportion of population living in households with access to basic services
		1.4.2 Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure
2 Zero hunger	2.1 By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round	2.1.1 Prevalence of undernourishment
		2.1.2 Prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES)
	2.2 By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons	2.2.1 Prevalence of stunting among children under 5 years of age
		2.2.2 Prevalence of malnutrition among children under 5 years of age, by type (wasting and overweight)
	2.3 By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment	2.3.1 Volume of production per labour unit
		2.3.2 Average income of small-scale food producers
	2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality	2.4.1 Proportion of agricultural area under productive and sustainable agriculture
	2.5 By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed	2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium- or long-term conservation facilities
		2.5.2 Proportion of local breeds classified as being at risk, not at risk or at unknown level of risk of extinction
	2.a Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries	2.a.1 The agriculture orientation index for government expenditures
		2.a.2 Total official flows (development assistance plus other official flows) to agriculture sector

	2.b Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round	2.b.1 Agricultural export subsidies
	2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility	2.c.1 Indicator of food price anomalies
3 Good health & wellbeing	3.3 By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases	3.3.2 Tuberculosis incidence per 100,000 population
6 Clean water & sanitation	6.3 By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally	6.3.1 Proportion of wastewater safely treated
		6.3.2 Proportion of bodies of water with good ambient water quality
	6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time
		6.4.2 Level of water stress: freshwater withdrawal as a proportion of available freshwater resources
8 Decent work & economic growth	8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7 per cent gross domestic product growth per annum in the least developed countries	8.1.1 Annual growth rate of real GDP per capita
	8.2 Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors	8.2.1 Annual growth rate of real GDP per employed person
	8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value	8.5.1 Average hourly earnings of female and male employees, by occupation, age and persons with disabilities
		8.5.2 Unemployment rate, by sex, age and persons with disabilities
	8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance and financial services for all	8.10.1 (a) Number of commercial bank branches per 100,000 adults and (b) number of automated teller machines (ATMs) per 100,000 adults
		8.10.2 Proportion of adults (15 years and older) with an account at a bank or other financial institution or with a mobile-money-service provider
9 Industry, innovation &	9.1 Develop quality, reliable, sustainable and resilient infrastructure, including regional and trans-border infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all	9.1.1 Proportion of the rural population who live within 2 km of an all-season road
		9.1.2 Passenger and freight volumes, by mode of transport
		9.3.1 Proportion of small-scale industries in total industry value added

infrastructure	9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	9.3.2 Proportion of small-scale industries with a loan or line of credit
10 Reduced inequalities	10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average	10.1.1 Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population
	10.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status	10.2.1 Proportion of people living below 50 per cent of median income, by sex, age and persons with disabilities
13 Climate action	13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	13.1.1 Number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population
		13.1.2 Number of countries that adopt and implement national disaster risk reduction strategies in line with the Sendai Framework for Disaster Risk Reduction 2015–2030
		13.1.3 Proportion of local governments that adopt and implement local disaster risk reduction strategies in line with national disaster risk reduction strategies
	13.2 Integrate climate change measures into national policies, strategies and planning	13.2.1 Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production
15 Life on Land	15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world	15.3.1 Proportion of land that is degraded over total land area
	15.4 By 2030, ensure the conservation of mountain ecosystems, including their biodiversity, in order to enhance their capacity to provide benefits that are essential for sustainable development	15.4.1 Coverage by protected areas of important sites for mountain biodiversity
		15.4.2 Mountain Green Cover Index
	15.5 Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species	15.5.1 Red List Index

Authors: Sarah Robinson and Martin Petrick

Recommended citation: Robinson, S. & M. Petrick (2021). Trade-offs among sustainability goals in the Central Asian livestock sector, SDGnexus Network Working Paper 01-2021. Center for international Development and Environmental Research (ZEU), Justus Liebig University Giessen. DOI: http://dx.doi.org/10.22029/jlupub-58

Front cover photo: Sarah Robinson

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German Academic Exchange Service (DAAD) grant number 57526248,
programme “exceed - Hochschulexzellenz in der Entwicklungszusammenarbeit”.