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Maximizing nutrition in key food value chains of Mongolia under climate change

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ABSTRACT

Mongolia's projected warming is far above the global average and could exceed 5 °C by the end of the century. The reliance on pastoral livestock and rainfed agriculture along with its fragile ecosystems put Mongolia's economy at risk of adverse climate change impacts, particularly from climate extreme events. Eighty percent of Mongolia's agricultural sector is concentrated in animal husbandry with around one third of the population relying on this livelihood. Beyond livestock, food production is concentrated in few crops: wheat; potatoes; and three vegetables (cabbage, carrot, and turnip). Climate change does not only affect food production but can exacerbate malnutrition by removing food and nutrients in all stages of the food value chain. To identify perceived effects of climate change and measures to reduce climate change impacts in Mongolia's's key food value chains, we implemented focus group discussions with 214 livestock and vegetable producers, traders, and food consumers. We also conducted 30 key informant interviews at the soum, provincial, and national levels across four agroecosystems in three provinces. Based on this community engagement analysis, we identify interventions that the government and private sector, including herders and farmers, should undertake to increase the food security and nutrition of the country's prioritized food value chains under climate change.

1. Introduction

Projections suggest that with climate change, extreme weather events are becoming more frequent, less predictable, and more violent (IPCC, 2023). These events are and will continue to have substantial impacts on the availability and access to sufficient, safe and nutritious foods (Willett et al., 2019). As the number and intensity of climate-related extreme events increases, the poorest populations, primarily those employed in agriculture, are often the most impacted (FAO, 2022b). While direct impacts of climate change on crop yields, associated higher food prices, and increased costs of healthy diets are increasingly understood (Fanzo et al., 2018; Myers et al., 2017), other linkages between climate change and nutrition have been less studied (Chimeddulam et al., 2008; FAO, 2022c; WB & ADB, 2021).

Less is known about the impact of climate change and climate-responsive agricultural approaches on nutrition outcomes, such as child growth and micronutrient status of women, children and households, and about how the adoption of climate smart agricultural practices at scale may influence the availability of micro- and macronutrient availability across food value chains and landscapes. The Feed the Future Gender, Climate Change and Nutrition Integration Initiative (GCAN) has worked with the United States Agency for International Deveopment (USAID) headquarters, field missions, and partners to enhance understanding between climate, gender, and nutrition toward enhanced resilience, women's empowerment, and nutrition outcomes in several Feed the Future countries. To better understand these

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interlinkages in Mongolia, an analysis of how to maximize nutrition outcomes in two value chains of key importance of Mongolia was undertaken in collaboration with the United Nations Children's Fund (UNICEF) and the Food and Agriculture Organization of the United Nations (FAO) offices in Mongolia.

Mongolia's projected warming is far above the global average and could exceed 5 °C by the end of the century. Under the highest and most likely emissions scenario (Representative Concentration Pathway (RCP) 8.5), Mongolia is projected to experience a rise in temperature of around 5.3 °C by the 2090's, compared to a global average of around 3.7 °C. There is also some agreement that precipitation will increase in Mongolia, depending on the agro-ecological zone, as a result of the accelerated water cycles—with increases in the range of 8%–14%. Higher precipitation can increase flash floods but is unlikely to counteract the drying of lakes given the large projected increases in temperatures. Moreover, the melting of remaining glaciers can lead to a substantial shift in hydrological regimes (WB & ADB, 2021).

The country's dependence on pastoral livestock and rainfed agriculture along with its fragile ecosystems put Mongolia's economy at risk of climate shocks and extreme weather events. Eighty percent of Mongolia's agricultural sector is concentrated in animal husbandry with around one-third of the population relying on this livelihood. Because of Mongolia's poorly diversified economy, 28% of the population still suffer from extreme poverty (WB, 2022). This continued poverty has downstream consequences for diets and the nutritional status of the population.

Limited crop production, mostly wheat, potatoes, and a small number of vegetables, mostly cabbage, carrot, and turnip, have led to the country's increased dependence on food imports to achieve a balanced diet. However, with global food prices projected to increase under climate change and other related shocks, Mongolia must focus on strengthening the resilience of domestic food value chains while considering opportunities for diversifying its agricultural production base.

Poorly diversified diets put Mongolians at risk for micronutrient deficiencies, food insecurity, and non-communicable disease risk. A recent nationwide survey of men and non-pregnant women of reproductive age found low consumption of healthy, nutrient-dense food groups including fruits, non-tuberous vegetables, eggs, nuts and seeds, fish and poultry, and whole grains; and excessive consumption of red meat (particularly by men), refined grains, and whole-fat dairy. It also found dietary inadequacy for 10 of 21 assessed nutrients, including fiber, folate, and vitamin D, while intake of protein, zinc, and vitamin B12 were adequate (Bromage et al., 2020). The most recent Mongolian National Nutrition Survey showed that 27% of young children (<5 years) and 21% of pregnant women are anemic, 70% of young children and 12% of pregnant women are vitamin A deficient, and 90% of young children and 96% of pregnant women have vitamin D insufficiency (Bater et al., 2019; Bromage et al., 2018; UNICEF, 2017). The prevalence of moderate or severe food insecurity was 26% in 2019–2021 and slightly more than half of the population (51.4%) could not afford a healthy diet in 2020 (FAO, 2022b). Compounding micronutrient deficits contributes to the growing burden of dietary-related non-communicable disease risks in Mongolia. Overweight or obesity affects 29% of schoolchildren and 63% of mothers and men, 61.9% of adults have elevated serum cholesterol, and 27.5% have high blood pressure. (Bromage et al., 2020; FAO, 2022a; NSO, 2021a; UNICEF, 2017).

A better and more comprehensive understanding of the linkages between climate change, food systems, diets, and nutrition is critical to ensure Mongolia's population has access to sufficient, safe, and nutritious food despite an unfavorable climate future. Mongolia's meat from mutton, beef, and goat and vegetable value chains are critically important for diets, nutrition outcomes, and climate change adaptation, and there is significant potential to improve these value chains to ensure they are more environmentally sustainable and resilient (FAO, 2022a; GoM, 2021; WB & ADB, 2021).

However, Mongolia faces formidable challenges. Climate change does not only affect food production but can exacerbate malnutrition by removing food and nutrients across all stages of food value chains (Fanzo et al., 2018). Yet, how value chains function in this new climate reality in specific country contexts is less studied from a nutrition lens, and more so, how climate change affects the production, marketing, and trade of these perishable, nutrient-dense food value chains and how these impacts are experienced by those who operate those chains (Spiker et al., 2023).

In Mongolia, livestock play an important role in food security, consumption, and pastoral animal husbandry traditions. According to the 2021 census (NSO, 2022) the country raised 67.3 million heads of livestock. There is also potential to grow certain vegetable commodity supply chains in the country to supplement the diet with micronutrients. Of the 591,200 hectares (ha) of arable land, only 3% (19,000 ha) are used for vegetable production and concomitantly, vegetable consumption remains low in the Mongolian diet (NSO, 2021b; Byambasukh et al., 2021; FAO, 2022a; GoM, 2021).

Using a qualitative, participatory methods approach, this study identified the perceived climate threats to two Mongolian food value chains—meat (high/excessive consumption) and vegetables (low consumption)—across the natural zones of Mongolia and the lived experience constraints put on the producers, traders, retailers, and consumers of these commodities. Following this qualitative analysis, a climate-nutrition-sensitive value chain analysis was undertaken to identify how climate and nutrition resilience could be maximized and nutrient losses minimized to reduce adverse climate change impacts on diets of the Mongolian population.

2. Materials and methods

2.1. Climate change impacts by geography

In 1996, Mongolia adopted five agroecological zones to identify suitable crop and livestock regions (Altansukh, 1996). Three regions were considered suitable for crop production. They include region I or Hangai-Khuvsgul, aligned with the High Mountain region, with annual precipitation levels of 200–400 mm; region II or Selenge-Onon with annual precipitation of 325 mm with the most productive agricultural areas; and region IV or Central and Eastern Steppe with annual precipitation of 130–225 mm. The other two regions were identified as non-crop growing regions in that they would need additional investment to be viable for crop production. These are region III or Altai with annual precipitation of 450 + mm and region V or Gobi Desert, with annual precipitation of less than 100 mm) (Tumurjav, 2015, Johnson et al., 2006; Altansukh, 1996, Klinge et al., 2018).

Each region is particularly suited for grazing herds, or producing cereal or grain crops, and fruits and vegetables due to the availability of pastures, number of growing season days, and annual precipitation. The main livestock include sheep, goats, cattle, yak, *khainag*, camels, horses, pigs, poultry, and non-domesticated herds while crops include cereal or grain crops (wheat, barley, oats, millet, fruits (apples, currants, sea-buckthorn, raspberry, plum, cherry) and vegetables (potato, cabbage, carrot, turnip, tomato, cucumber, garlic, leek, shallot, welsh, onion, spinach, rhubarb, radish, pea, siberian kale, sugar beet, soybean, kanola, common bean, pepper) (Altansukh 1996; Johnson et al., 2006).

According to RCP 8.5 2040–2059 projections, Mongolia will experience less precipitation (0–25 mm) and higher temperatures (an increase of 3.00 °C) in region V, higher precipitation (25–50 mm) and higher temperatures (2.75 °C) in region I, and elevated precipitation (50–75 mm) and temperature increases (2.50–2.75 °C) in the prime growing area of region II, which covers the forest steppe and steppe natural zones. It is expected that livestock will suffer from heat stress as a result of higher temperatures, reduced water availability, and lower quantity/quality of fodder. Further exacerbating livestock stressors are overgrazing, soil erosion and soil dryness, and land use change contributing to the reduction in pasture and crop land availability or suitability (Li et al., 2021; Han et al., 2021; Sankey et al., 2018; Klinge et al., 2018; Fawzy et al., 2020).

Severe winter storms (*dzuds*) have historically occurred in the Mongolian Gobi region, increasing in frequency and intensity over time (Shinoda, 2012), increasing risk of exposing livestock to extreme cold and dehydration resulting in mass livestock deaths. Although herders have developed resilience measures to mitigate and manage these risks (Fernandez-Gimenez et al., 2012; Taylor, 2014; Vova et al., 2015; Tumurjav, 2015), more frequent severe events could introduce new stressors to value chains that not only result in greater livestock loss, but also health consequences to herders (Groppo and Kraehnert, 2016).

2.2. Methods and data

Focus Group Discussions (FGD) and Key Informant Interviews (KII) were undertaken to understand the perceived constraints on critical value chains – animal foods and vegetables – in Mongolia. FGDs were conducted with herders and vegetable growers in eight soums[1] representing four of the country's five natural zones that are aligned with its agro-ecological zones. The livestock value chain was represented by sheep and the vegetable value chain by carrots. A total of 19 FGDs were conducted, including 11 with herders, 7 with vegetable growers, as well as one FGD with vegetable growers in the capital city of Ulaanbaatar. Eight FGDs were conducted with men, eight with women, and three with mixed-gender groups. A total of 214 participants participated in the FGDs, of whom 61% were herders, 39% were farmers, 48% were men, and 52% were women.

The herders and vegetable growers who were interviewed are considered knowledgeable representative members of local herding and farming communities and were selected in collaboration with local government agencies.

KIIs were undertaken with representatives of each link in the vegetable and meat value chains. Key actors from the government, private sector, and civil society were identified at the *soum,* provincial, and national levels and were intentionally selected based on their experience, knowledge, and information related to the two value chains. Using a purposive selection strategy, a total of 30 informants were interviewed, including livestock and vegetable producers at the *soum* level; meat and vegetable processors and traders, public officers at the province level; and representatives of abattoirs and meat processing plants, the Ministry of Food, Agriculture and Light Industry, associations, and researchers at the national level. The directors of the Mongolian Meat Association, the Mongolian Greenhouse Entrepreneurs Association, the Academy for Climate Change Development, and the Mongolian Biotechnology Association were also interviewed. Fig. 1 presents the *soums* and provinces where FGDs and KIIs were conducted.

The focus groups and interviews lasted approximately one hour and were recorded and transcribed with permission from the discussants and key informants. We obtained informed consent from all research participants. All interview transcripts and notes were de-identified and secured in password-protected documents to ensure respondent confidentiality. Drawing on the findings from a literature review, questions were focused on the successes and challenges of value chains amid climate change.

To analyze the results, we conducted a thematic analysis in Microsoft Word, drawing on information from the focus groups, the key informant interviews and collected literature. We initially coded the collected data under the broad categories of climate threats to livestock and vegetable production and supply chains, and climate adaptation strategies to livestock and vegetable production and supply chains. To minimize bias and validate the accuracy of the findings, two individuals coded the data simultaneously and the data sources were triangulated, always corroborating information from focus groups and interviews with written sources.

[1] A soum is the second level of the administrative division.

3. Results

3.1. Perceived climate threats and nutrition linkages across the two value chains

Respondents in all four agro-ecological regions noted experiencing adverse climate change impacts, with the largest impacts identified in the production phase. Fig. 2 summarizes the drivers and consequences of perceived climate change on meat production for each selected *soum*.

Table 1 illustrates the consequences of climate change impacts for the herds. Herders identified five main perceived impacts of climate change across all agro-ecological zones, namely (1) winds and storms, (2) high frequency of heavy rainfall events and flooding, (3) heat stress and drought, (4) seasonal changes (later summer and warming in winter), and (5) desertification.

Perceptions and views of herders are illustrated below. One herder from Bornuur (Tuv province, forest steppe zone) noted:

> "…*We do not know when heavy rains, floods, and storms will occur. Therefore, there is a high risk of losing livestock in storms*."

They also noticed adverse effects from perceived climate changes, such as reduced animal fattening and weight gain, increased mortality, and deterioration of herders' livelihoods– are common in the selected natural zones. The complex interlinkages between climate change and livestock outcomes are described by a herder from Bayankhongor province:

> *"Well, it is indeed linked to climate change. Animals need to gain weight and fatten up with meat in July. However, due to the weather changes, the rain arrives late in July. This causes animals to gain more fat, which can negatively affect the quality of their meat. Moreover, when the rain eventually arrives, it is often accompanied by sudden cold weather. This sudden and extreme change in temperature causes the animals to deteriorate immediately, lose weight rapidly, and can even lead to death."*

As a result of climate change, meat and meat products lose quality (and nutrients), and waste is likely to increase in the later stages of the value chain. This reduces the availability of meat and livestock products, such as milk, increases prices, and affects food security and public health. The unpredictability of seasons also affects other livestock products, as one herder from the Bayankhongor province expressed:

> *"In the past, dairy products were produced in summer when summer came in May and June, but in recent years, summer has arrived close to July, and when we start making dairy products, it is almost autumn."*

Herder FGD participants also noted other challenges that might be worsened by climate change. One women herder from Khuld in the Dundgobi province noted:

> *"In our location we do not have good veterinary services. Herders decide by themselves and give medicines and injections themselves. There is a high risk of having drug residues in meat."*

FGDs with vegetable growers were conducted in *soums* representing three natural zones: Bayankhongor *soum* of the Bayankhongor province in the High Mountain zone; Bornuur and Jargalant *soum* of the Tuv province in the Forest Steppe zone; and Ulziit *soum* of the Bayankhongor province in the Desert Steppe zone. Fig. 3 shows the perceived signs of climate change in the production phase of the vegetable value chain for each of the *soums*. Table 2 illustrates the perceived impacts of climate change on vegetable production by agro-ecological zone. Vegetable growers identified five common signs of climate change across all agro-ecological zones, namely (1) winds and storms, (2) less precipitation, (3) desertification or soil degradation, (4) heat stress and drought, and (5) extreme cold in early autumn.

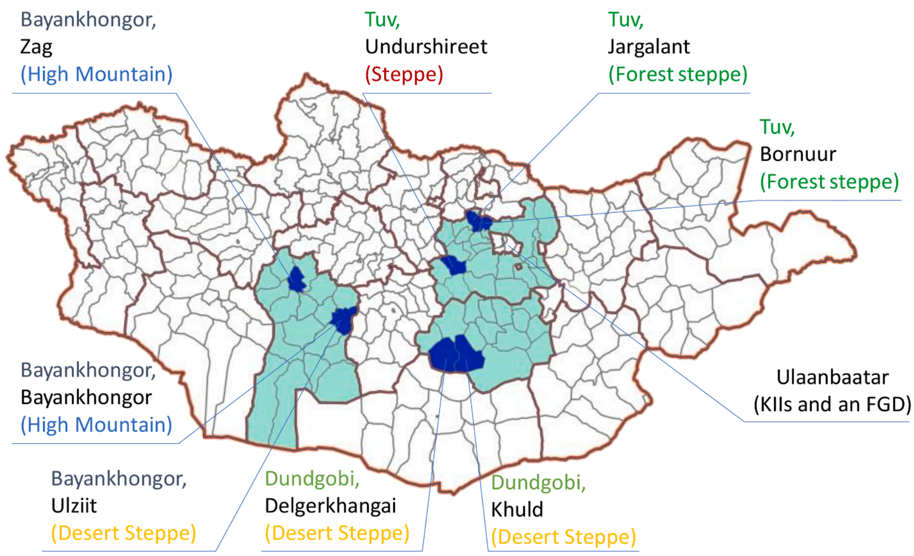

Fig. 1. Provinces and *soums* where FGDs and KIIs were conducted.

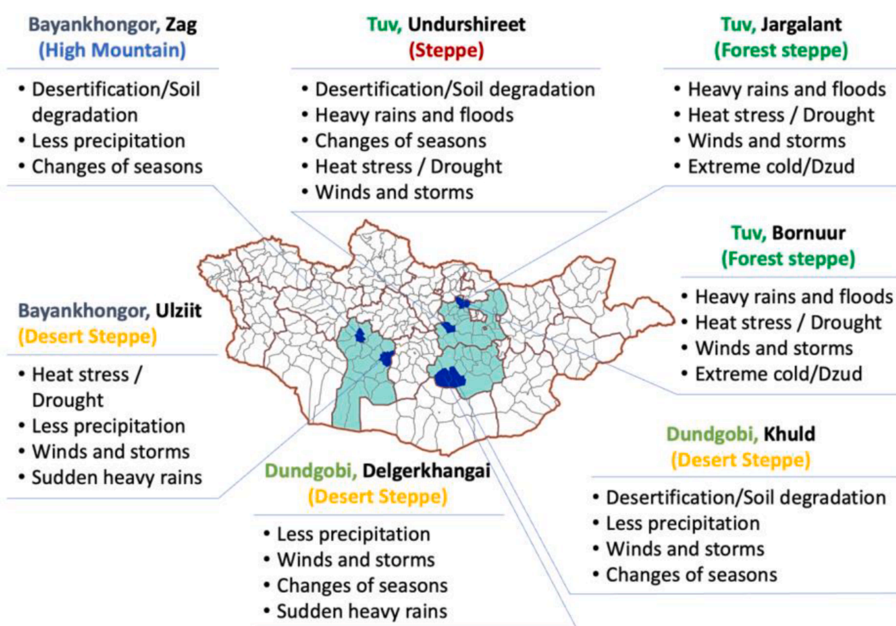

Fig. 2. Signs of climate change perceived by herders or stakeholders associated livestock.

Adverse effects of climate change, such as deterioration of soil fertility and erosion, decreased yield, declines in the quality and nutritional content of vegetables, and insufficient income to support vegetable growers are common. In addition to the abovementioned impacts, the participants representing the Forest Steppe zone, which is part of the prime agricultural region in Mongolia, mentioned negative impacts such as late/delayed germination, growth and maturation, and the emergence of plant diseases. One female vegetable producer from Bornuur *soum* noted:

> "*the quality of vegetables is deteriorating due to the lack of minerals in the soil.*"

Similar to the livestock value chain, vegetable farmers focused on challenges at the production stage:

> *"There are some difficulties in growing potatoes and vegetables due to climate change. For example, the prices of potatoes and vegetables, which are a source of livelihood, have been stable for the last ten years, i.e., prices have not increased, but capital inputs, and labor costs have increased, and the yield per hectare of potatoes has been steadily declining over the last ten years." – male vegetable grower from Jargalant.*
> *"Almost all kinds of vegetables are imported from China, and therefore the quality is not good, and the chemical content is high, perhaps." – a female vegetable grower from Bayangkhongor.*

While herders and vegetable farmers did not directly discuss post-harvest, storage, and retail challenges, they identified seasonality in affordability of key food staples, which suggests challenges in storage and processing of foods, including milk and vegetables. As an example, a female herder from the desert steppe in Delgerkhangai, Dundgobi *soum* noted:

> "*Herders do not have facilities to store large quantities of vegetables, so they buy them in small quantities.*"

Table 1
Impacts of climate change on livestock production by natural zone.

Climate change impacts	High Mountain	Forest Steppe	Steppe	Desert Steppe
Desertification/ Soil degradation	- Decreased pasture vegetation - Weight loss - Increased mortality - Decreased yield		- Weight loss - Sand movement	- Decreased pasture vegetation - Weight loss
Unpredictable seasonal changes	- Weight loss, smaller livestock, and decreased yield - Deterioration of livelihoods - Lack of dairy products		- Weight loss, smaller livestock, and decreased yield	- Increased weeds - Weight loss - Grass and plants grow later, and decreased pasture vegetation - Increased otor migration through provinces and soums
Winds and storms	- Decreased yield - Increased mortality - Decreased income and deterioration of livelihoods	- Livestock chased down by winds and storms- Gers (yurts), houses, and fences destroyed - Livestock covered by snow - Animals have nothing to eat - Increased mortality	- Decreased yield- Gers (yurts), houses, and fences destroyed	- Livestock chased down by winds and storms - Increased mortality/ miscarriage - Decreased income - Gers, houses, and fences destroyed
Heavy rainfall and flooding		- Freezing of animals - Soil swept away - Livestock chased down by rainfall - Increased mortality	- Livestock swept away - Deterioration of pastures and soil	- Increased mortality - Deterioration of pastures and soil
Heat stress and drought		- Decreased hay yield and pasture vegetation - Weight loss and decreased yield	- Decreased hay yield and pasture vegetation - Weight loss and decreased yield	- Delayed growth of grasses - Weight loss - Livestock cannot be sold - Deterioration of livelihoods
Less precipitation	- Decreased pasture vegetation - Weight loss - Increased mortality - Deterioration of livelihoods - Decreased yield			- Deterioration of pastures and pasture vegetation
Extreme cold (dzud)		- Weight loss - Increased mortality - Animals have nothing to eat		

Similarly, women vegetable growers from Ulziit soum in the Bayankhongor province stated:

> "*There is an issue about storage. Because there is no storage, we cannot use our own vegetables in the spring.*"

However, women herder respondents from the Dundgobi province, Khuld *soum,* expressed that most herders now have freezer and fridges, and many use small fridges attached to their vehicles and wagons. One female herder stated:

> *"We cannot say the livelihood of herders worsened. In the countryside there are almost no families without cars and motorcycles. With their own cars, herders can travel to the aimag [provincial] city to sell their wool and cashmere… and buy their food."*

A livestock processing company in the Tuv province noted processing challenges linked to climate change and livestock populations that surpass carrying-capacity:

> *"Due to overgrazing pasture and late summer in most of the aimags that supply livestock to Mongolia, the number of animals with sufficient weight gain delivered to the factory is insufficient. Herders have been supplying livestock to the factory since August [only] due to the late summer and the inability to gain weight early. As a result, the factory was not operating for two months without raw materials and lost revenue."*

The processor also identified challenges with traditional slaughtering practices:

> "*Herders or intermedient players slaughter animal in non-factory way and transport the meat to the central meat markets and shops in Ulaanbaatar by non-designated vehicles, so especially during the warm season it leads to deterioration and contamination of the meat."*

Several women respondents from Delgerkhangai *soum*, Dundgobi province noted that vegetables and other foods could only be accessed during certain times in a year. A female producer added:

> *"Due to the weather conditions of the year, the supply of milk and dairy products varies, and when the weather is good, there is an abundance, and in a year with drought and dzud the tea is without milk."*

The FGD participants also made it clear that their incomes are often insufficient to afford a more diverse diet. As one women herder from Delgerkhangai *soum* noted:

> "*Consumption of vegetables varies depending on purchasing power. One with more livestock consumes more, and one with few animals consumes less*."

Similar statements were made by women vegetable farmers. For example, a woman from Ulziit soum in the Bayankhongor province said:

> "*Low-income households buy cheaper, leaner meat, and cheaper potatoes and vegetables, which have been stored for a long time, shrunken, and of poor quality*."

The women herders furthermore identified lack of time as well as the

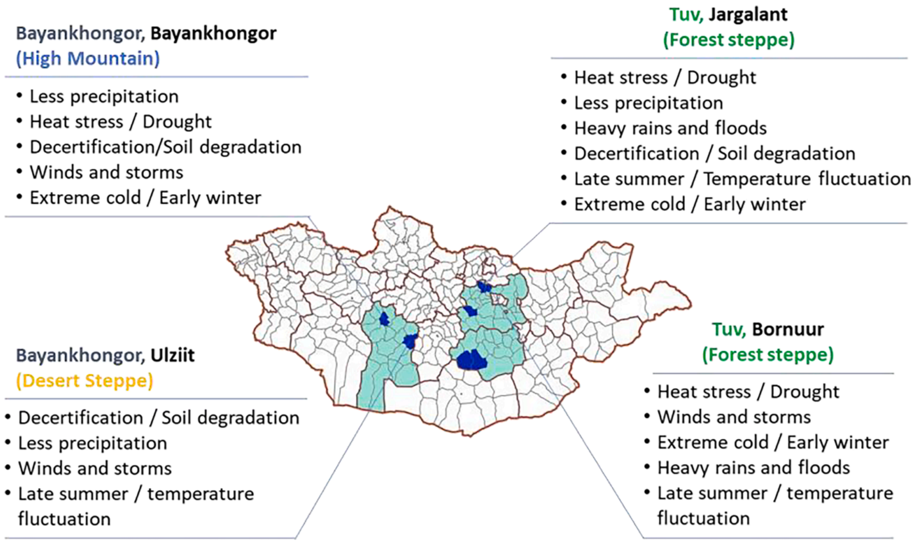

Fig. 3. Signs of climate change perceived by vegetable growers.

separation of wives from their husbands when children start school and move to the *soum* centers as challenges affecting diets. Women herders from Delgerkhangai *soum* noted:

> "*We can't have a meal on time because we herd and follow animals all the time… we even can't feed our children on time. We only feed our children during free time.*"

But even vegetable farmers have limited time to prepare meals for their children. As one woman from Ulziit soum stated:

> "*We go out in the morning and come back in the evening due to the agricultural work, so the children feed if there is anything ready to eat at home.*"

If parents cannot take time to prepare healthy meals, children more likely resort to consuming ultra-processed foods or foods of limited diversity. Separation of men herders from their spouses was noted as an issue affecting diets by several women. As an example, a woman herder from Khuld soum said:

> *"With the school starting age of 6 years, young herders' wives usually live in the soum center to take care of the children and the husband mostly does the herding alone. So there are no possibilities to have a meal on time as well as thinking about a healthy diet."*

Similarly, the women herders noted additional challenges with expanding dietary diversity of their children. Women herders from Delgerkhangai *soum* stated that:

> "*Rural children are not used to eating vegetables very well…the children have not learned to eat vegetables.*"

This suggests the need for increased awareness raising and knowledge transfer on the importance of vegetables for Mongolian diets in rural areas in addition to the importance of making vegetables available in processed form for better storage, such as in cans and at more affordable prices. The need for nutrition education is also confirmed by conversations with the vegetable producers in Bayankhongor soum in the Bayankhongor province, including:

> *"There is an issue that lack of awareness of people how to use the leafy vegetables, [and] people do not know how to use broccoli…most of us consume different kinds of Chinese vegetables, which are usually less nutritious."*

At the same time, when asked about the causes of poor health, women herders in Delgerkhangai *soum* as well as from other regions identified "unhealthy diets" and "excessive consumption of fat intake" suggesting some awareness of Mongolia's unhealthy dietary intake patterns. However cultural traditions remain significant regarding diets. One female herder noted:

> *"Herders do not understand that by changing ingredients of their meal we can make the food to be more nutritious. Instead, they think that making variety of dishes such as tsuivan, buuz and huushuur, with the same and less amout of ingredients, is more diverse. In other words, herders think diversity is the number of dishes rather the number of different ingredients."*

Finally, women herders from Dundgobi noted existing challenges to secure drinking water, stating that "during summer we use surface water," and "in winter, we melt snow." Similarly, men herders from Jargalant *soum* in the Tuv province noted: "We spend our summers in Belkh. If you don't get water at 4 in the morning, you won't be able to get water during the day", and "people and animals are drinking from the same river." With increased drying up of water sources linked to climate change, drinking water, an important source of nutrients and minerals will need to be increasingly obtained over larger distances and at higher cost.

3.2. Climate adaptation strategies for nutritious value chains

A climate-nutrition-sensitive value chain analysis was undertaken to understand better how these two commodities can be improved to maximize climate and nutrition resilience and minimize nutrient loss and climate impacts to one of the most vulnerable countries in the world. This analysis is based on a range of studies that examined value chains from a nutrition perspective but much less so from a climate angle (Allen & De Brauw, 2018; Fanzo et al., 2017; Gelli et al., 2015; Maestre et al., 2017; Morgan et al., 2019).

Fig. 4 summarizes the factors to maximize nutrition entering value chains (upper boxes) and minimize nutrition exiting value chains (lower boxes) of meat and meat products from the KIIs and FGDs . Low pasture carrying capacity and remote pastures without watering points reduce livestock nutrition and thus animal growth and quality at the input supply stage. Lack of precipitation reduces pasture quality and results in lower meat quality. This can be addressed by irrigating pastures, establishing artificial ponds, and growing perennials on pastures.

Similarly, as noted by a key informant from the Ministry of Food, Agriculture and Light Industry, with too many hot days, animals' body weight, yield, carcass weight, and meat protein content decrease,

Table 2
Impacts of climate change on vegetable production by natural zone.

Climate change impacts	High Mountain	Forest Steppe	Desert Steppe
Winds and storms	- Soil degradation - Decreased yield - Vegetables dried up	- Soil degradation - Fences destroyed - Decreased nutrition	- Soil degradation - Decreased nutrition
Extreme cold in early autumn	- Frozen vegetables - Late/delayed maturation - Lost harvest	- Decreased yield - Frozen seeds - Deterioration of quality - Lost harvest - Late/delayed maturation - Emergence of plant diseases	- Lost harvest - Deterioration of quality
Less precipitation	- Decreased yield - Lost harvest	- Decreased yield	- Decreased yield - Rivers and springs dried up
Desertification or soil degradation	- Lost harvest	- Soil degradation - Decreased yield - Increased cost and decreased income	- Soil degradation - Decreased yield - Deterioration of quality
Heat stress and drought	- Decreased yield - Lost harvest	- Decreased yield - Decreased nutrition - Rivers and springs dried up - High costs of irrigation, tillage, fertilizer, and machinery, and decreased income - Late/delayed germination - Invasion of pests	
Heavy rainfall and flooding		- Harvest swept away - Decreased yield - Deterioration of crop/vegetables, invasion of pests, and increased weeds - Emergence of plant diseases - Late/delayed maturation	
Late summer/temperature fluctuation		- Late/delayed maturation - Poor/delayed germination - Deterioration of quality and nutrition of vegetables - Lost harvest	

connective tissue increases, muscle water retention quality deteriorates , and the meat becomes too hard, moistureless, and tasteless. Pregnant animals are less likely to withstand climate extremes, and calving is often intentionally reduced to ensure animal survival. This requires investment into better breeds that are more adapted to a hotter climate future in the country.

At the production stage, lack of access to finance and labor shortages, the lack of acceptance of *otor* herders (pastoralists who migrate into other regions to escape *dzuds*) in other provinces and *soums*, and inaccurate forecasts of bad weather events reduce livestock productivity. On the other hand, fodder banks, better management of *otor* movements, and improved forecasting of extreme events can reduce the loss of livestock productivity during the production stage.

At the processing and slaughter stage, deterioration of meat and meat products due to lack of cold storage and cooling vehicles affects the quantity and quality of meat produced. Better transportation, storage, and trade will be needed to address this. The biggest challenge in the processing phase is the traditional meat preparation, mainly in herders' homes, instead of abattoirs. Local slaughtering can lead to food contamination, foodborne illness, adverse health effects and substantial food waste.

At the consumption stage, more information needs to be disseminated on healthy diets, with a focus on diversifying diets toward more consumption of fruits and vegetables. In addition, the dominance of meat consumption in pastoralist diets threatens herders' food security and nutrition as livestock production is subject to significant climate risks.

Fig. 5 summarizes the factors that maximize (top boxes) and minimize (bottom boxes) nutrition in the vegetable value chain. In the input supply stage, poor-quality soils affect vegetable production. Developing climate change- and drought-resistant seed varieties and enhancing farmers' knowledge of soil protection techniques can improve the production and productivity of vegetables. Due to variable weather, some crops freeze due to sudden frosts during harvest, resulting in reduced yields and nutrients. Sudden fluctuations in air temperature and loss of crops due to heavy rains and floods are not uncommon.

At the production stage, financial and labor shortages, insufficient machinery, equipment, and irrigation, and lack of knowledge and skills in agricultural technology and improved practices have a negative impact on the quality and quantity of vegetables produced. Because vegetable producers are predominantly considered informal, they are excluded from government-provided economic and financial support. Incentives from the Crop Production Support Fund are provided to large-scale, grain-growing enterprises. Very little government support exists for small/marginal vegetable-growing households. The establishment of cooperatives, capacity building on agricultural technology and best practices, and more direct government support could help grow vegetable production.

At the processing stage, the lack of cold storage and cooling vehicles affects fresh vegetables' storage, transportation, and distribution. Moreover, few vegetable processing plants are in operation. As a result, processing enterprises and household growers do not always comply with best practices. These issues can be addressed by following good practices and standards for transportation, storage, and trade. Fresh vegetables can also be processed to prevent spoilage and waste, through drying or canning. As rural populations have limited time preparing healthy meals, recipes using dried and canned vegetables should be provided through television and other channels accessible in rural areas.

Moreover, vegetable consumption remains low due to limited knowledge of the importance of dietary diversity of Mongolian consumers, including low culinary literacy of how to prepare non-traditional vegetables. These issues can be addressed through guidelines, labeling, and mass media that promote a balanced, healthy, and nutritious diet and raise awareness of the negative impacts of consuming unhealthy ultra-processed foods.

For both the meat and vegetable value chains, the slaughter (livestock) and post-harvest (vegetable) stages are key bottlenecks that result in low economic benefits to producers, poor diversity of diets of producers (particularly in the case of herders), high risks of adverse climate change impacts, and lack of overall diversification of agricultural systems in the country.

4. Discussion and conclusion

4.1. *The Mongolian challenge*

Mongolia is highly susceptible to the impacts of climate change, and the agriculture and animal husbandry sectors are vulnerable to extreme weather events. While food security and undernutrition have been declining in the country, these trends could be reversed with growing

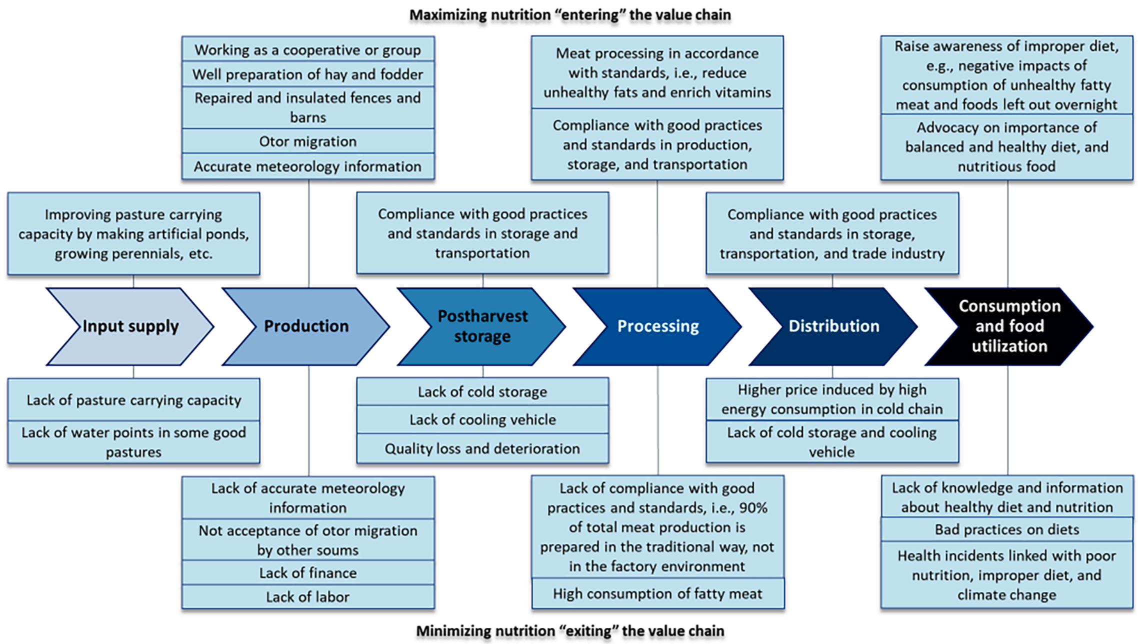

Fig. 4. Factors that maximize and minimize the nutrition of meat and meat products.

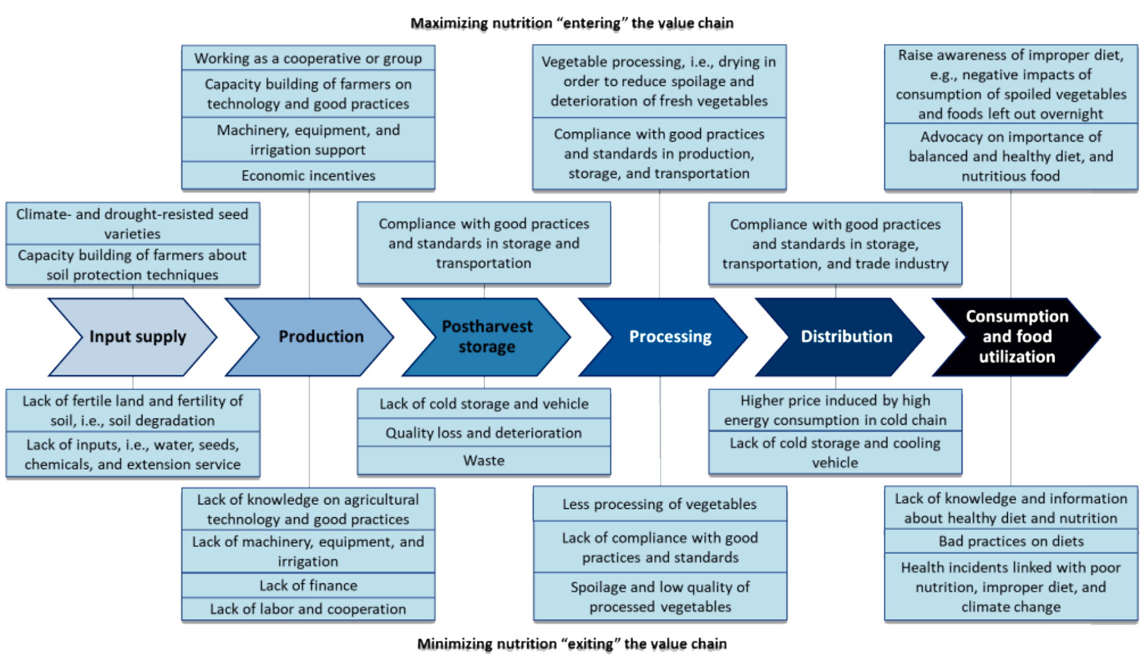

Fig. 5. Factors that maximize and minimize the nutrition of vegetable products.

climate change impacts. The new risk is poor diets and diet-related non-communicable diseases. Mongolia's agriculture system also contributes to natural resource degradation and climate change. At the same time, the Mongolian diet is not meeting nutritional requirements and is responsible for much of the country's greenhouse gas emissions, as well as nutrient run-off into water bodies. Substantial efforts will be needed to not only improve diets to mitigate climate change and address rising non-communicable diseases and continued micronutrient deficiencies, but also to stave off further food insecurity that climate change will bring (Bater et al., 2019). Improving sustainable practices associated with agriculture and animal husbandry will be essential to ensure that these systems do not further contribute to natural resource declines but also promote long-term livelihoods.

4.2. *Climate impacts on value chains in Mongolia: Lived experiences*

Climate change significantly impacts the entire value chain for livestock and vegetable products for herder households and vegetable growers. Therefore, understanding the lived experiences of producers is critical to providing context-specific solutions to help producers cope and adapt to climate change.

Based on the views and perceptions from producers, climate change is having the most significant impact on the production stage of the meat value chain, reducing both the supply and quality of meat. Most of those who participated in the discussions reported that reduced rainfall led to a lack of soil moisture supply during pasture vegetation growth and reduced pasture plant diversity and yield, reducing livestock live weight. Yield per animal is declining due to deteriorating livestock quality. According to key informants in the study, rising temperatures, pasture degradation, and changes in the water supply affect animal nutrition and meat and milk quality.

Like the meat value chain, climate change has the most significant impact on the production stage of the vegetable value chain, reducing both the quantity and nutritional quality of vegetables. Key issues include freezing of crops due to sudden frosts during harvest, resulting in reduced yields and nutrients, loss of nutrients due to instability of heat during crop growth or sudden fluctuations in air temperature, and loss of crops due to heavy rains and floods. Because of reduced soil fertility , the yield per hectare has not changed and has even declined in some areas. Soil fertility continues to decline due to wind, water erosion, pest infestation, and soil contamination by chemicals and other causes.

4.3. Policy recommendations for Mongolia to adapt to a changing climate for improved diets and nutrition

To address the substantial number of risks that climate change poses to these key value chains, we propose a series of investments andpolicies, as well as the institutional and human capacity building to ensure that value chains are both climate- and nutrition-sensitive for Mongolia.

For the livestock sector, it will be important to invest in diverse livestock breeding strategies that focus on improving growth yields, and that are tolerant to weather extremes. The focus should be on quality, not quantity and extensification. The environment to raise livestock must also be improved. Building fodder banks and watering points in strategic areas to support herders, particularly with *dzud* events and decreasing the need for *otor* migrations. Digital technologies that provide climate forecasting and other climate service data are critical for herders to forecast, prepare, and minimize risk. And last, infrastructure support for abattoirs and cold storage facilities across the country are necessary to improve the quality of meat, ensure food safety, and reduce food waste. These key investments must be made by the government and private sector entities with real-time support by livestock and agriculture extension and non-governmental organizations.

For the vegetable sector, improving infrastructure and building capacity is critical for producers to adapt to climate change. As far as infrastructure, greenhouses supported by solar energy systems and cold chain storage and transport provide dual benefits for the environment as well as livelihoods to get fresh vegetables to the market. The processing of vegetables is also critical to increase their value and increase availability of vegetables to remote herders. Extension services could facilitate processing cooperatives to consolidate yields and allow for vegetable producers to reach distant markets. Vegetable growers in Mongolia need support and technical capacity to diversify the types of vegetables that can be grown depending on the agro-ecosystem, as well as management practices to reduce food loss. Finally, unlike livestock production, vegetable producers operate in an informal realm. The establishment of cooperatives, capacity building on agricultural technology and best practices, and more direct government support could help increase vegetable production.

At the same time, all respondents noted deficiencies in the awareness of what constitutes a healthy diet beyond the knowledge that too much fatty meat can cause adverse health consequences. These awareness gaps are further compounded by the limited time of rural food producers, the separation of young herder families when children turn six years of age, the lack of accessible vegetables that can be stored, and limited availability of affordable foods throughout the year. Most respondents agreed that some foods were simply not affordable for most consumers during part of the year or during the entire year. Concerted investment in food production, processing, and storage should help address the affordability challenge but will need to be complemented by continued awareness raising campaigns on the importance of healthy meals using diverse ingredients.

These recommendations can also be translated to other local contexts where nomadic pastoralists and horticulture producers face the stark realities of climate change. This includes parts of Central Asia, and parts of North and West Africa for pastoralists and Central Asia and much of Sub-Saharan Africa for horticulture producers.

The methodologies used in the study also have broader implications. While most climate change impact studies in the food systems space focus on production, this study has shown that climate change also affects other links in food value chains, such as food processing and transportation. Moreover, the study notes the increased importance of raising awareness of the health benefits of diverse, high quality diets. Availability of foods is often already affected by seasonal weather, and these impacts will be more pronounced by climate change. Particularly governments with poor rural infrastructure should consider undertaking similar value chain analyses to identify bottlenecks for nutrition along all links of the chain and to identify preventive investment, institution and awareness raising measures.

It is hoped that by capturing the views and lived experiences of those facing the everyday realities of climate change, policymakers and the private sector can make sound, swift investments that are locally relevant and substantively support the livelihoods of Mongolian herders and producers.

Statements and declarations

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Informed consent

Informed consent was obtained for all respondents and research was conducted in line with the ethical standards established and approved by the authors’ institutions.

CRediT authorship contribution statement

Kadirbyek Dagys: Conceptualization, Methodology, Data curation. **Bakyei Agipar:** . **Soninkhishig Tsolmon:** . **Claudia Ringler:** Conceptualization. **Kristen Bellisario:** . **Jessica Fanzo:** Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The datasets generated and analyzed during the current study are not publicly available because of their containing information that could compromise the privacy of research participants but excerpts are available from the authors on request.

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