Climate smart agriculture practices in the context of Georgia's climate mitigation efforts

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1 Introduction

From 2021, Georgia is entering a new era of climate mitigation policy planning. The first-ever 2030 National Climate Strategy and 2021-2023 Action Plan (CSAP) was adopted by the Government of Georgia in 2021 alongside the revision of the Nationally Determined Contribution (NDC) to the Paris Agreement. These strategic documents were the first to be approved by the newly established Climate Change Council, which oversees climate planning and processes.

The agriculture sector is a new focus of climate change mitigation planning efforts. The newly established Climate Smart Agriculture working group oversaw the development of the agriculture chapter for the CSAP, which contained little in the way of immediate measures with significant direct emission reduction potential, but which highlighted many priority areas for future action, and many areas where there is a need for more technical analysis to inform options.

This report provides an overview of the landscape for mitigation action in the agriculture sector in Georgia, and potential access points for international climate finance.

Section 2 provides an overview of GHG emissions and trajectories in the agriculture sector; these emission trajectories informed the analysis for the development of the 2021 Climate Strategy Action Plan. **Section 3** provides an overview of potential mitigation actions in the sector, differentiated according to the accessibility of the measures in terms of the marginal abatement costs and technological readiness. **Section 4** develops a framework to consider the finance needs of different areas of mitigation potential within the sector and looks at the potential sources of international climate finance for agriculture in Georgia. **Section 5** highlights the non-climate benefits associated with mitigation action in agriculture, focusing on synergies with the EU-Georgia Association Agreement and the Sustainable Development Goals.

2 Agriculture GHG emissions and trajectories

In 2020, the agriculture sector employed around 40% of the Georgian population, most of them are categorized as "self-employed" which usually means that they are small-scale subsistence farmers. However, the sector's contribution to national GDP has been declining, from 25% in 1999 to 8.4% in 2020 (GEOSTAT, 2021). 43% of Georgia's total land area is agricultural land, including 324,000 ha of arable land, 120,800 ha of permanent crops and roughly 2 million ha of pasture and meadows (FAOSTAT, 2020). In 2013-2019, GEL 1.5 billion from the state budget of Georgia was spent on agricultural development (Transparency International Georgia, 2020). However, government programs were mainly of social nature rather than aiming at increasing the climate performance of the sector.

2.1 Trends and emission drivers

The current government is projecting a rise in production levels mainly due to the expected development of large-scale commercial agriculture, making it crucial to embed sustainable business practices from the beginning onwards to ensure a sustainable long-term pathway for the sector (Winrock and Remmisia, 2017). Various projects are now in place to help make the Georgian agriculture sector more productive and profitable. On the one hand, this may lead to increased GHG emissions through increased activity but, on the other, may decrease future emissions through high productive livestock or a more sustainable use of resources.

Agricultural development is already one of the priority areas of the Georgian Government as outlined in the 'Agriculture and Rural Development Strategy of Georgia 2021-2027'. The strategy particularly considers the implementation of climate smart agriculture practices although there are currently few specific concrete plans for the achievement of that objective (MEPA, 2019b).

Figure 1 presents an overview of historical GHG emissions for the agriculture sector in 2015[1]. The agriculture sector accounted for approximately 19% of GHG emissions (3.31 $MtCO_2e$) in 2015. In 2015, emissions from enteric fermentation accounted for the majority of the sector's GHG emissions (44%), followed by emissions from agricultural soils and manure management, accounting for 41% and 14% of emissions, respectively (MEPA, 2019b). Energy-related emissions represented just about 1% of the sector emissions, excluding emissions from agricultural vehicles (e.g., tractors and others), which are currently accounted within the Climate Strategy and Action Plan under the transport sector, under "off road vehicles".

[1] The modelling exercise in this report has been prepared as an input to the Climate Strategy and Action Plan 2021 and does therefore not take into account the newest emissions data for 2016 and 2017 published in Georgia's Fourth National Communication later that year.

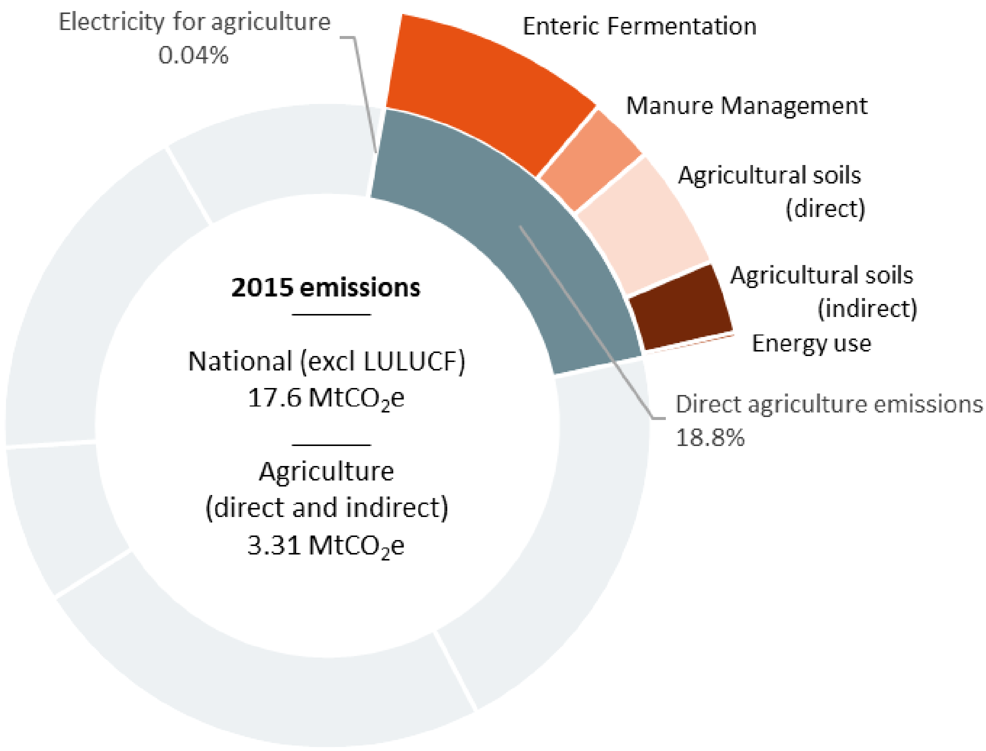


Figure **1:** Agriculture sector GHG emissions breakdown in 2015 based on data from MEPA (2019)

2.2 Climate change commitments, targets and plans

While the steady growth of the agriculture sector comes with several challenges, Georgia is also currently navigating its responsibilities to international climate change negotiations under the Paris Agreement and the collective mitigation efforts of all countries. This section sets out the implications of the Paris Agreement and national climate change planning processes for the agriculture sector.

2.2.1 The Paris Agreement

In December 2015, representatives of 196 nations negotiated a global agreement for responding to the threat of climate change, at the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris. The objectives of the Paris Agreement are to strengthen the global response to climate change by keeping global temperature rise to well below 2 °C above pre-industrial levels, pursue efforts to limit the temperature increase even further to 1.5 °C, and to strengthen the ability of countries to deal with climate change impacts.

As a country with high vulnerability to the impacts of climate change, Georgia stands at the international level for strong and ambitious action from the Parties of the UNFCCC; Prime Minister Irakli Garibashvili highlighted in 2015 that Georgia considers itself a "leader and an ambitious partner in addressing climate change" (Garibashvili, 2015). Georgia ratified the Paris Agreement in 2017. Table 1 gives an overview of available independent analysis on what Paris Agreement compatibility will require from the agriculture sector at the global level.

Table 1: Implications of the Paris Agreement targets for the agriculture sector globally

Indicator / subsector	Implications of Paris Agreement for required pathways
Emissions (whole sector – global targets)	**2 °C:** Global annual agriculture emissions must decrease by approximately 11-13% by 2030, compared to BAU projections (Wollenberg *et al.*, 2016). Non-CO_2 emissions, including those from the agriculture sector, should be net-zero by around 2085 (UNEP, 2016). **1.5 °C:** Global annual agriculture emissions must decrease by approximately 30-50% by 2030, compared to BAU projections (Wollenberg *et al.*, 2016). Non-CO_2 emissions, including those from the agriculture sector, should be net-zero by 2060-2080 (UNEP, 2016).
Emissions intensity (whole sector)	**2 °C:** Emission reduction targets can be met by 2025 if producers would adopt the best practices currently applied by 10-25% of producers that have the lowest emissions intensities (Climate Action Tracker, 2016).
Research and development	Many of the potential technologies and practices for broader emission reductions are not yet available; significant resources should be invested in continued research and development of these technologies and practices (Climate Action Tracker, 2016).

Source: Day et al. (2017)

Support provisions under the Paris Agreement may provide technical or financial assistance for the decarbonisation of the agriculture sector. Parties have pledged to collectively mobilise USD 100 billion per year for climate change mitigation and adaptation action, although current pledges fall significantly short of this.

Regular monitoring and communication of progress at the sector level in the agriculture sector will be required for compliance with the Paris Agreement. In the Paris Agreement text, Parties agreed that they shall be required to regularly communicate the status of NDC implementation, broader efforts towards pursuance of the Paris Agreement, and support needs for enhanced action, and that these communications shall be subject to technical expert review. Agriculture sector authorities and relevant statistical offices in all countries will need to cooperate with national UNFCCC focal points.

2.2.2 Nationally Determined Contribution

Nationally Determined Contributions (NDCs) identify short- and medium-term action or targets which Parties commit to for pursuance of the long-term objectives of the Paris Agreement. Parties are required to update their NDCs by 2020 and at least every five years thereafter, enhancing their targets in line with developments in national circumstances. In addition, Parties are also requested to present long term low emission development strategies (LTS) which outline countries' plans for the long-term transformation of sectors in line with the goals of the Paris Agreement. Georgia's medium-term contribution to the Paris Agreement is represented by the 2021-updated NDC, which outlines Georgia's planned targets and action up to 2030. Georgia's NDC includes climate change mitigation targets and measures and notes that adaptation measures will be covered in a separate National Action Plan for Adaptation.

Georgia's 2021-updated NDC sets out an unconditional NDC mitigation target of a 35% reduction of economy-wide GHG emissions below 1990 levels in 2030, or a 50-57% reduction subject to collective progress at the global level to follow a trajectory aligned with the objectives of the Paris Agreement, and the provision of international support (Government of Georgia, 2021). Economy-wide emissions (excluding land-use, land-use change and forestry) are projected to increase on average 4% per year between 2020 and 2030, under the baseline, without measures to reduce emissions. On this trajectory, emissions would reach 30.8 $MtCO_2e$ in 2030, a total increase of 75% compared to 17.6 $MtCO_2e$ in 2015. By comparison, the 35% reduction target beneath 1990 levels set out in the NDC would limit GHG emission growth to a maximum of 27.2 $MtCO_2e$ in 2030. **The NDC does not include a sector-specific quantitative target to decrease GHG emissions but states to "support the low carbon development of the agriculture sector".**

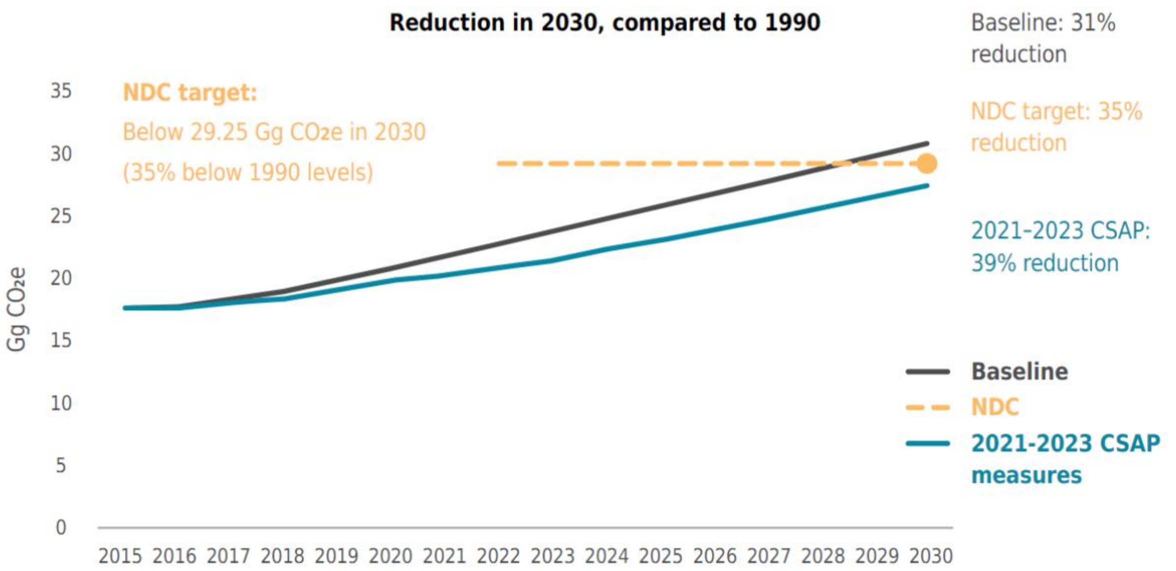


Figure 2 shows that the activities indicated in the 2021-2023 Climate Strategy and Action Plan (CSAP) would already suffice to bring emissions levels to the NDC target level in 2030, indicating that a more ambitious GHG emission reduction target for 2030 may be achievable if additional mitigation activities can be identified in the next iterations of the Climate Strategy Action Plan.

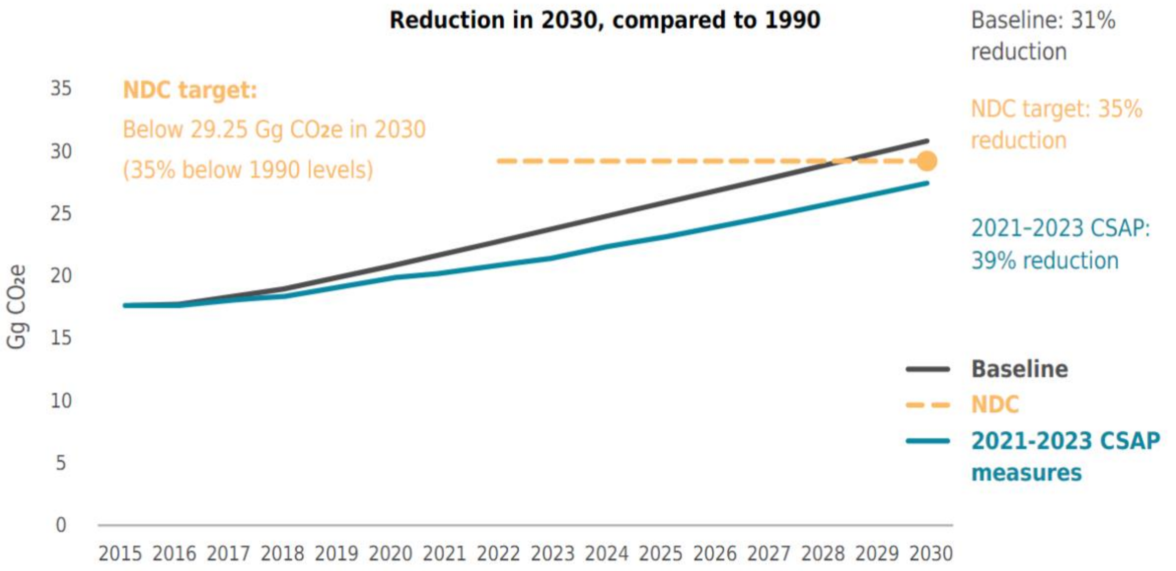


Figure 2: Economy-wide GHG emission trajectories for Georgia (2015-2030)

2.2.3 Climate Strategy and Action Plan

Georgia's first 2030 National Climate Strategy and 2021-2023 Action Plan (CSAP) was adopted in 2021. The CSAP is a national strategic policy document containing a list of committed policy actions for each sector, designed to set Georgia on the pathway to implementing its NDC.

While the Strategy will remain in place until 2030, the Climate Action Plan (CSAP) is to be updated every 2-3 years, informed by new developments within the sectors, and the monitoring and evaluation reports from the previous CSAP. The Ministry of Environmental Protection and Agriculture (MEPA), through the Climate Change Division (CCD), is responsible for overseeing the regular update of the CAP, as mandated by the National Climate Change Council which oversees the development of all climate change planning processes in Georgia. The Ministry of Environmental Protection and Agriculture (MEPA) involves other relevant institutions from across all ministries, as well as national experts, in the development of the CAP.

Agriculture is included in the CSAP as one of seven key sectors for climate change mitigation action. Informed by parts of the analysis presented in this document, governmental and civil society stakeholders from the agriculture sector identified actions for reducing emissions in the sector and creating an enabling environment for enhanced emission reductions in the future.

2.3 Scenarios for GHG emission trajectories

2.3.1 Reference emission trajectory

The reference emission trajectory for the agriculture sector provides an overview of how greenhouse gas emissions from the sector have and are projected to develop in the period from 1990 to 2030. The methodology and data sources used for the development of a reference trajectory are presented in Annex I. While most recent available data from the National Statistics Office of Georgia (GEOSTAT) and international data sources has been used, it is important to note that future modelling would benefit from improved data collection at the national level.

Under the reference scenario, **emissions from the agriculture sector are projected to increase by approximately 40% to 4.623 $MtCO_2e$ in 2030** compared to 2015 levels (Figure 3).

Emissions from agricultural soils are projected to increase by 60% between 2015-2030 and account for the majority of the overall projected growth in sector emissions. The main source of agriculture soil emissions projected for 2030 are pasture range and paddock with 32% of total soil emissions (2015: 29%), nitrogen leaching and runoff with 26% (2015: 31%), and the use of synthetic fertilizers with 19% (2015: 23%).

The anticipated industrialisation of livestock farming is a major driver in the growth of emissions from the livestock sector. Cattle livestock is projected to increase by 18%, swine livestock by 250% and poultry livestock by 133% as industrialized livestock farming is assumed to start operating in 2021 and to steadily grow from there (Winrock and Remmisia, 2017). Enteric fermentation emissions are projected to increase by 17% between 2015 and 2030, while emissions from manure management increase by 47%. Cattle was the source of 92% of emissions from enteric fermentation and 82% of emissions from manure management in 2015 and would remain the major source of these emissions up to 2030.

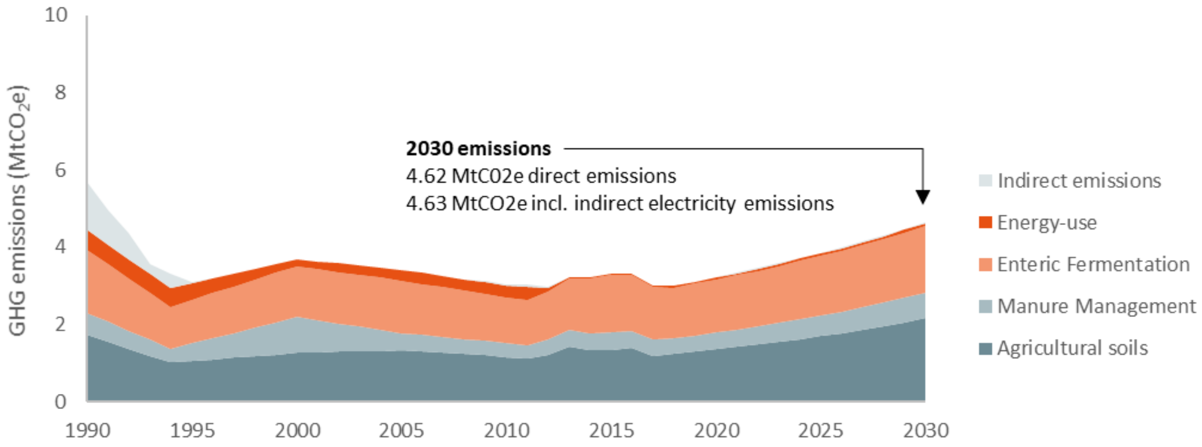


Figure 3: Reference scenario emission trajectory for agriculture (1990-2030)

2.3.2 Climate Strategy and Action Plan emission trajectory

The Climate Strategy and Action Plan (CSAP) emission trajectory for the agriculture sector provides an overview of how greenhouse gas emissions from the sector may deviate from the reference scenario up to the year 2030, in the case that all of the identified actions are fully implemented. The methodology for the development of a the CSAP trajectory is presented in Annex I.

Under the Climate Strategy and Action Plan scenario, **agriculture sector emissions continue to increase from 3.310 $MtCO_2e$ in 2015 (direct emissions only) to 4.617 $MtCO_2e$ in 2030** (+40% compared to 2015 levels) after considering the impact of the suggested policy. These emission levels represent a less than 1% reduction, or 7 $ktCO_2e$, in 2030 compared to the reference scenario.

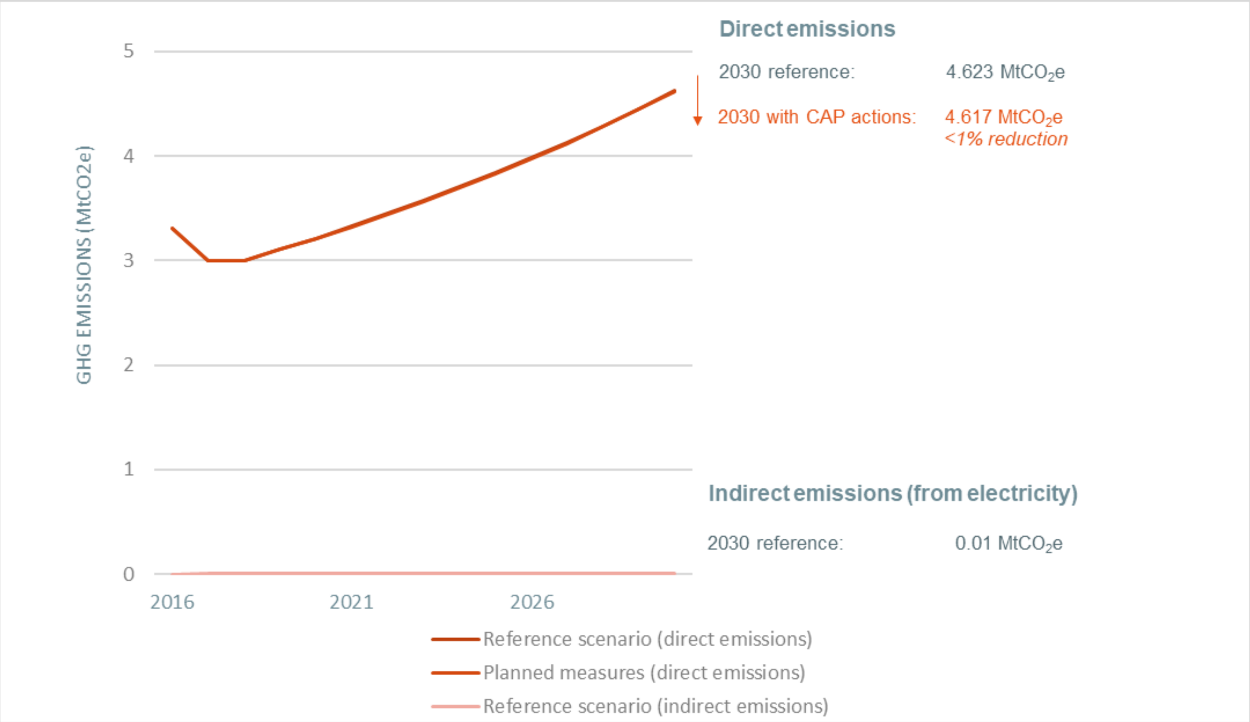


Figure 4: Impact of proposed measures of the Climate Strategy and Action Plan for the agriculture sector on the reference case emission trajectory (imperceptible in graph given a reduction of less than1%)

3 Measures for climate change mitigation in agriculture

This section provides an overview of the spectrum of potential climate change mitigation measures across Georgia's agriculture sector. Sections 3.1, 3.2 and 3.3 evaluate livestock supply side measures, cropping systems supply side measures and demand side measures respectively, while section 3.4 provides an overview summary of the spectrum of potential action. Although emissions from farming machinery are not counted towards agriculture emissions in Georgia's inventory, the impact of zero-emissions equipment has been deemed relevant for this set of measures and included in Section 3.2.

The evaluation of each measure includes an indication of the mitigation potential as well as the accessibility. The accessibility of the measure is considered in terms of current status of the technology or measure in Georgia, the costs associated with implementation, as well as the main requirements for unlocking further action for broader implementation. This evaluation is based on the review of available national and international literature.

The 20 mitigation measures evaluated in this section have been identified from desk research on national and international literature. These measures range from those that are mature and established at the international level, to less certain measures and technologies on the horizon that remain in research and development.

3.1 Livestock supply-side measures

The following mitigation options for the supply side of the livestock sub-sector could be pursued, or are on the horizon for the future. Several unexploited options exist although they are limited in their decarbonisation potential. Additional technologies and practices are being researched and developed and may be available in the future.

3.1.1 Grazing land management

Measure Measures to manage grazing land including nutrient management, fire management, controlling grazing intensity and improving grass varieties, can improve the carbon sink capacity of grazing soils and reduce the release of nitrous oxide.

Status Sustainable management of grazing land is significantly undervalued in Georgia in many regions, due to the long-term uncertainty of land tenure. The management of pasturelands remains relatively unregulated.

Potential Approximately 210 ktCO_2e in 2030: Grazing land management in warm-dry climate zones is estimated to have a climate change mitigation potential of approximately 0.11 tCO2e per hectare of grazing land each year (Smith *et al.*, 2007).

Costs Low (~1-50 USD/tCO_2e): Adjustments to farming techniques do not necessarily require higher inputs or costs once established, while the improved sustainability of the pastures may lead to an economic gain that may partially or completely offset any upfront costs.

Unlocking Land tenure policy, regulation and awareness: Farmers will improve the sustainability of their land management if they are made aware of the techniques to do so, and if land tenure is secure enough to support a long-term vision for land management. Regulations that put in place minimum standards or incentives for good practice may also support change but can be cumbersome to implement for smaller-scale farming.

3.1.2 Livestock manure management

Measure The capture and utilisation of biogas from livestock manure can reduce GHG emissions through methane avoidance.

Status Technologies are mature in some markets but are not yet in widespread use in Georgia, due to low awareness and poor accessibility to microfinance. Since the introduction of a net metering regulation in 2017, conditions for biodigester use are significantly more attractive for farm operators, who can generate savings or revenue from the utilisation of captured biogas.

Potential Approximately 500 ktCO2e in 2030: Biodigesters could reduce manure emissions by up to 80% in 2030, assuming 90% penetration of the most efficient technologies (Winrock International, 2017). Emissions from livestock manure in Georgia are projected to reach 660 ktCO_2e in 2030. Existing biodigesters in Georgia have reduced emissions from methane avoidance by more than 55% on the sites where they are installed (OECD, 2006).

Costs Moderate (~50-100 USD/tCO_2e): The abatement cost of biogas capture and utilisation from manure management at the global level is approximately 92 USD/tCO_2e (Ahmed *et al.*, 2020). Costs for farmers may be significantly lower now in Georgia since the introduction of a net-metering regulation in 2017.

Unlocking Awareness campaigns and affordable credit for upscale: Anaerobic digesters are available, and broader uptake may be feasible if farmers are supported with affordable microcredit for upfront capital expenditures, made aware of the benefits, and trained in their operation.

3.1.3 Livestock feed optimisation

Measure The composition of livestock feed can be optimised to reduce enteric fermentation. Feedstock optimisation is a longer-term process since determining the optimal feedstock for a specific region requires an iterative learning process on how local breeds of cattle respond to different locally available vegetation and grains.

Status The optimisation of livestock feed for enteric fermentation is not practiced in Georgia, although it has been identified in the 2021 Climate Strategy and Action Plan as a priority action, conditional on the receipt of international support. As a first step, the CSAP targets moderate feedstock improvements for 20% of cattle.

Potential Approximately 300 ktCO_2e in 2030: It is estimated that emissions from fermentation could be reduced by approximately 7% through feedstock optimisation in the Eastern European region (Smith *et al.*, 2007). Estimates for Georgia in the 2015 Low Emissions Development Strategy indicate a higher potential in Georgia (Winrock International, 2017).

Costs Moderate (~50-100 USD/tCO_2e): Optimised feed may be more expensive, and the iterative process of determining the optimised feed mix entails risks for farmers, since the impacts of feedstock changes – which could be either positive or negative for agricultural production – may not be clear in advance (Harmsen, 2019; Ahmed *et al.*, 2020).

Unlocking Investment in demonstration and research: Farmers will need to be financially supported to take part in trial and demonstration projects until locally appropriate solutions have reached more maturity and market saturation. Those trial and demonstration projects will also support necessary further locally-specific research to determine optimised feedstocks for Georgia.

3.1.4 Livestock breeding optimisation

Measure Selective breeding of livestock can introduce species with higher productivity, resulting in lower emissions per unit of produce, or with reduced emissions from enteric fermentation.

Status Georgia currently has plans to move ahead with selective breeding and the introduction of larger high-yielding cattle. The immaturity and lack of breed-specificity of genetics programs can inhibit implementation at scale (Ahmed *et al.*, 2020).

Potential Approximately 110 ktCO_2e in 2030: Breeding optimisation can lead to a 7% reduction in the emissions from enteric fermentation in beef cattle (Smith *et al.*, 2007), an emissions source projected to account for approximately 1.6 MtCO_2e in 2030.

Costs Cost-neutral or cost-beneficial (~ < 0 USD/tCO2e): An economic gain can be derived from increased productivity per head or unit of input (Harmsen, 2019; Ahmed *et al.*, 2020).

Unlocking Investment in trialling and demonstrating specific breeds in the Georgian context. Uncertainty on the right solutions for the Georgian context may currently represent a barrier for farmers to make own investments.

3.1.5 Livestock health monitoring and disease prevention

Measure Monitoring and improving the health of livestock can decrease the rate of disease and output loss, decreasing the emissions intensity of production.

Status The National Food Agency (NFA) implements activities related to monitoring animal health and coordinating veterinary services. Those activities have received significantly greater priority in Georgia, largely driven by requirements of the EU Association Agreement, with a tenfold increase in spending from the NFA between 2010 and 2019 (World Bank, 2020). Food safety and veterinary activities accounted for approximately 21% of public spending in the agriculture sector in 2019.

Potential Approximately 85 ktCO_2e in 2030: Health monitoring and improvements could reduce the emissions intensity of livestock production by approximately 5% (Harmsen, 2019). This is a conservative estimate, since in lower and middle-income countries the potential for livestock health improvements is likely to be higher.

Costs Low (~1-50 USD/tCO_2e): The costs of health monitoring and management are partially offset by the economic gain associated with decreased disease and losses (Harmsen, 2019; Ahmed *et al.*, 2020).

Unlocking Investment in scaling up health monitoring and veterinary activities.

3.1.6 Direct methane capture from cattle

Measure Devices that can be worn by cattle may be able to capture methane directly at the point of emission, either directly converting methane to carbon dioxide and water vapour or capturing it for utilisation as biogas.

Status The technology is not yet available. Prototype devices for direct methane capture are emerging and undergoing trials. Those devices are yet to reach the market in any country.

Potential Uncertain: Initial trial results from one prototype device indicate a 53% reduction potential for methane emissions from enteric fermentation on cattle while they are wearing the device, but this is yet to be tested at scale and over longer time periods.

Costs Low (~1-50 USD/tCO_2e): Devices coming to market have a moderate upfront cost but are designed to be worn uninterrupted for years and may have a high emission reduction efficiency.

Unlocking Next steps are dependent on developments at the international level. Georgia could invest in research and development, or could wait to adopt technologies produced in other countries.

3.1.7 Advanced inhibition of enteric fermentation

Measure Emissions from enteric fermentation could be further inhibited through anti-methanogen vaccinations, or novel feed additives.

Status The technology is not yet available. Anti-methanogen vaccinations are under development and have been used in small-scale trials in a handful of countries (WRIGHT, 2004; Zhang *et al.*, 2015). The state of scientific knowledge on feed additives for inhibiting enteric fermentation is regularly advancing, and novel options may be expected to come to market in the future.

Potential Unknown.

Costs Unknown.

Unlocking Next steps are dependent on developments at the international level. Georgia could invest in research and development, or could wait to adopt technologies produced in other countries.

3.2 Cropping systems supply-side measures

The following mitigation options for the supply side of the cropping systems could be pursued, or are on the horizon for the future. Many options already exist that could turn cropping systems into a net-sink for carbon, while there are a range of new technologies and practices currently emerging from research which could provide even more possibilities for climate change mitigation in the future.

3.2.1 Zero-emission farm machinery and equipment

Measure The full electrification of farm machinery and equipment, including battery-powered tractors, harvesters and dryers, can reduce the direct emissions associated with energy use in agriculture.

Status Most of the technologies are not yet available in Georgia. The electrification of large-scale farm machinery and equipment is not yet widespread in any country, but there are prospects for these technologies to become competitive in the mid- to longer-term future.

Potential Up to 100 ktCO2e in 2030: Most of the emissions from energy use in agriculture could be reduced by the electrification of farm machinery and equipment, if combined with the generation of renewable electricity.

Costs High (> 100 USD/tCO_2e): As zero-emission vehicle technologies further develop and become cheaper to manufacture, they may eventually become a cost-competitive alternative to diesel-powered machinery in many countries. However, since the majority of farms in Georgia make use of older imported equipment, the high capital expenditure to acquire zero-emission machinery in likely to remain comparatively expensive for the foreseeable future.

Unlocking Finance for demonstration: When a market for zero-emission farming machinery becomes accessible for Georgia, finance for demonstration projects will be required to overcome high upfront capital costs.

3.2.2 Low tillage practices

Measure Practice to reduced tillage and the retention of tillage residues can significantly improve the soil term quality of soils through enhanced soil aggregation, water retention and organic activity. Methods such as strip tillage, chiselling, disking, and no-till planting lead to the retention of crop residues as a covering to prevent soil erosion. This increase the carbon capture capacity of soils as well as reducing the release of nitrous oxide.

Status Conservation- or zero-tillage is not widely practiced in Georgia. In most cases, there are no significant technological barriers to the adoption of low-tillage practices. Some practices require less machinery than conventional tillage cultivation, or can even be easily performed manually without machinery. The uptake of low-tillage practices is also negatively affected by lack of awareness and a short-sighted approach to land management, exacerbated by land property right issues.

Potential Approximately 150 ktCO_2e in 2030: Cropland plant management in warm-dry climate zones is estimated to have a climate change mitigation potential of approximately 0.35 tCO_2e per hectare of cropland land each year (Smith *et al.*, 2007).

Costs Cost-neutral or cost-beneficial (~ < 0 USD/tCO2e): Savings can be incurred through decreased use of labour and heavy machinery for conventional tillage (Ahmed *et al.*, 2020).

Unlocking Training and awareness campaigns; regulatory change: The benefits should be attractive to farmers if they are aware and trained in plant management practices. Regulatory change to ensure long-term security of land-tenure will also further boost sustainable practices.

3.2.3 Cropland plant management

Measure Soil quality can be significantly enhanced through the high-input of diverse organic plant material. This includes crop rotation and the use of cover crops. The high organic input increases the carbon capture of the soil, and ensures a more efficient use of soil nitrates, and a reduction of nitrous oxide emissions.

Status Unknown and requiring further investigation.

Potential Approximately 170 ktCO_2e in 2030: Cropland plant management in warm-dry climate zones is estimated to have a climate change mitigation potential of approximately 0.39 tCO_2e per hectare of cropland land each year (Smith *et al.*, 2007).

Costs Low (~1-50 USD/tCO_2e): Changes in planting practices do not necessarily require higher inputs or capital expenditures (McKinsey & Company, 2009).

Unlocking Training and awareness campaigns; regulatory change: The benefits should be attractive to farmers if they are aware and trained in plant management practices. Regulatory change to ensure long-term security of land-tenure will also further boost sustainable practices.

3.2.4 Cropland water management

Measure The application of harvested water to irrigate croplands is an increasingly important measure for climate change adaptation in the agriculture sector. Water harvesting and irrigation techniques may increase the resilience of cropland to drought and other extreme local or temporal weather events. Irrigation can have a significant positive impact for climate change mitigation due to the increased carbon sequestration potential of well-watered soils, as well as the increased production yield of the land which leads to a relative reduction in the emissions intensity of agricultural produce. However, the irrigation of land may also lead to an increase in the application of synthetic fertiliser and an increase in nitrous oxide emissions. Accordingly, this measure is best pursued in combination with other conservation agriculture measures, including organic soil restoration and low-tillage agriculture, to reduce soil erosion and offset the potential increase in the demand for synthetic fertiliser. Depending on the method of harvesting and irrigation, additional energy inputs and associated emissions may also be incurred. Potential negative effects for emissions can also be reduced through the use of drip- or sprinkler-irrigation systems which require significantly less input and entail less soil erosion than flood irrigation.

Status The share of irrigated cropland in Georgia has increased significantly in recent years from approximately 10% in 2012 to approximately 25% in 2020 (World Bank, 2020). Irrigation has been prioritised by the national government, as indicated by the development of the 2017-2025 Irrigation Strategy for Georgia which includes the target to reach 200,000 hectares of irrigated cropland by 2025 (approximately 45% of cropland)(Ministry of Agriculture and LTD Georgian Amelioration, 2017). Public spending in infrastructure for irrigation and drainage increased six-fold since 2012 to account for 27% of public spending in agriculture in 2019. Irrigation practices can have negative effects because of runoff and water erosion as well as the salination of fields with dissolving salts and carbonates. To date there are no quality requirements for irrigation water in Georgia; raising groundwater levels make the water more vulnerable to be contaminated with mineral fertilizers and pesticide residues. Further, a significant amount of irrigation water is lost during transportation via old or malfunctioning ditches and channels. Future action should therefore focus on the improvement of transportation channels as well as regulating the use of irrigation water.

Potential Approximately 120 ktCO_2e in 2030, if the share of cropland irrigated would be increased to approximately 50% by 2030: Water management in warm-dry climate zones is estimated to have a climate change mitigation potential of approximately 1.14 tCO_2e per hectare of additionally irrigated cropland land each year (Smith *et al.*, 2007), but can also have negative consequences if combined with increased fertiliser use or energy-intensive practices.

Costs High (> 100 USD/tCO_2e): Based on the costs of irrigation and drainage programmes in the past years, upfront capital costs can be high, especially since the most accessible irrigable land is already being irrigated. Higher precision drip-irrigation technologies are more expensive still. However, costs are entirely location specific and dependent on locally available water resources; in cases where water is easily accessible and where yields are significantly improved, irrigation may be cost-neutral or even cost-beneficial.

Unlocking Investment in scaling up: Investments into irrigation and drainage systems have significantly increased the proportion of irrigated land in recent years.

3.2.5 Synthetic fertiliser management

Measure A reduction of synthetic fertiliser application, achieved for example through more precise application of fertiliser and more deliberate timing of application, can significantly reduce the emissions of nitrous oxide associated with the overuse of synthetic fertilisers. The overuse of synthetic fertilisers does not derive a productivity benefit, although results in costs and environmental degradation.

Status Georgia has, in a short period of time, become highly reliant on synthetic fertiliser. The use of synthetic fertiliser in Georgia increased from 35 kg per hectare of arable land in 2010, to 150 kg in 2015, as the Georgian economy and the value of agricultural output, has grown (World Bank, 2017). The current level of fertiliser input is now considerably higher than the global average.

Potential Approximately 100 ktCO_2e in 2030: Around 20% of the GHG emissions associated with synthetic fertiliser use could be offset through simple fertiliser management techniques, as seen in Montenegro (Government of Montenegro, 2020).

Costs Cost-neutral or cost-beneficial (~ < 0 USD/tCO2e): The reduction of fertiliser input through more efficient application may entail cost savings for farmers without necessarily affecting yields (McKinsey & Company, 2009; Ahmed *et al.*, 2020). In the longer-term, deeper reductions in fertiliser application can significantly improve the quality of soils (see *organic soil restoration*).

Unlocking Training and awareness campaigns; regulatory change: The short- and long-term benefits of reduced fertiliser use should be attractive to farmers if they are aware and trained in practices for more efficient fertiliser application, or the use of alternative organic inputs. Public investments in fertiliser subsidies could in some cases be carefully redirected to training and awareness campaigns for fertiliser management. Regulatory change to ensure long-term security of land-tenure will also further boost sustainable practices.

3.2.6 Organic soil restoration and production

Measure The organic restoration of soils takes the reduction of synthetic fertiliser a step further, to regenerate stable and fertile organic soils that do not require synthetic fertiliser. This involves a combination of several measures in addition to the reduction of synthetic fertiliser application, such as the increased application of manure on soils, and the revegetation of soils with shrub and creeper species. The regeneration of organic soils can reduce nitrous oxide emissions associated with synthetic fertiliser use.

Status Approximately 0.3% of cropland in Georgia was under organic agricultural production in 2017 (FAO, 2020a). In theory, organic agriculture is highly accessible; the measures available for organic soil restoration are mostly well-established practices that do not require the availability of new technologies. Uptake is hindered by a lack of awareness on the benefits of organic agriculture. In many areas of Georgia, uncertainties related to long-term land tenure rights also lead to a more short-term perspective for farming practices and a reduction of the perceived value of measures that result in the longer-term sustainability of soils.

Potential Approximately 400 ktCO_2e in 2030: Organic soils are estimated to have an increased carbon sequestration potential pf 0.9-2.4 tCO_2e per hectare each year (Muller *et al.*, 2016).

Costs Low (~1-50 USD/tCO_2e): Organic produce may fetch premium prices, while the costs for agricultural inputs may be reduced (McKinsey & Company, 2009; Muller *et al.*, 2016). Since it may take several seasons for organic fertility of soils to be restored, potential yield reductions in the short-term may cause organic farming to be perceived as a more costly option.

Unlocking Awareness and training; regulatory change: Regulatory change to ensure long-term security of land-tenure, combined with awareness and training on organic agriculture and its long-term benefits, could enable farmers to changes to their practices.

3.2.7 Biochar application

Measure Biochar is a charcoal-like substance created through the combustion of woody biomass in a process called pyrolysis. Biochar can be added to soils to increase their carbon sequestration and fertility. The production and use of biochar can lead to a reduction of greenhouse gas emissions through several means: in the production process, carbon from biomass is converted to a stable form of captured carbon which may not decay for hundreds of years; the pyrolysis process creates renewable energy which can be captured and utilised for heating or generation, offsetting other energy generation requirements; biochar increases the fertility of soils, reducing the need for synthetic fertilisers and the nitrous oxide emissions associated with their use; the increased fertility of soils may also lead to increased plant growth, which further increases the carbon sequestration of the land.

Status Different forms of biochar are being trialled in several different agricultural applications in many developed and developing countries worldwide, although biochar is not a fully matured practice and is not in widespread use. The application of biochar is not yet practiced in Georgia.

Potential In the order of 400 ktCO_2e in 2030: The potential of biochar for carbon sequestration and the reduction of other GHG emissions remains the subject of research and is highly dependent on local climatic and soil conditions. Estimates at the global level range from 1.4-2.9 GtCO_2e per year to 6 GtCO_2e per year (Chatterjee and Lal, 2009). The lower end of this range would imply a carbon sequestration potential of 0.89 tCO_2e/ha on croplands.

Costs Cost-neutral or cost-beneficial (~ < 0 USD/tCO2e): Abatement cost estimates range significantly worldwide due to uncertainties in the abatement potential of the practice, as well as significant differences in the cost of the production process in different countries. Several studies indicate that the production and use of biochar could be cost-neutral or cost-negative in many regions, including Asia, due to the significant benefits for farmers and the potential for energy utilisation (FAO, 2009; Pratt and Moran, 2010). Abatement cost estimates in Europe are slightly higher but still relatively low, ranging from EUR 20-45 /tCO_2e in 2030 (Teichmann, 2015).

Unlocking Investment in demonstration projects: The initiation of a first wave of demonstration biochar projects in Georgia would lead to increased awareness and gaining first experiences to better understand the local potential of the measure.

3.2.8 Agroforestry

Measure Agroforestry involves the deliberate planting of trees in croplands and on pastoral lands. Carbon sequestration is increased through the trees as well as the higher carbon sequestration of soils. This can include inter-cropping for the purpose of producing both agricultural and forestry-related produce, and boundary planting for demarcation and protection against eroding forces, among other forms.

Status Approximately 25% of Georgian cropland in 2018 was accounted for by orchards and vineyards, much of which could be already classified as agroforestry (National Statistics Office of Georgia, 2020). Aside from this, the extent of deliberate agroforestry in cropping systems in Georgia is relatively low. Conditions for agroforestry may be favourable in some locations; more extensive agroforestry is more feasible on smaller and non-mechanised agricultural plots, which still represent a significant but ever reducing portion of Georgia's agriculture sector. Agroforestry is also more feasible in locations where there is a good market for wood-related produce, which is generally the case in Georgia where demand for forestry-produce – especially for energy – drives significant illegal logging. Agroforestry is highlighted in the CSAP as well as Georgia's Country Programme with the GCF as a national mitigation priority.

Potential Approximately 50 ktCO_2e in 2030: Agroforestry on croplands in warm-dry climate zones is estimated to have a climate change mitigation potential of approximately 0.33 tCO_2e per hectare of suitable crop land each year (Smith *et al.*, 2007). The area of agricultural land which could be feasible for agroforestry in Georgia has not been assessed; in some other Asian countries, approximately 42% of croplands were assessed to be suitable for agroforestry (Makundi and Sathaye, 2004).

Costs Low (~1-50 USD/tCO_2e): Upfront capital expenditures for planting forested areas on cropland are often quite low, while part of these costs may be recouped if there is an easily accessible market for forestry-related produce (Makundi and Sathaye, 2004), which is the case in Georgia.

Unlocking Targeted awareness campaigns for high potential regions; land-tenure regulation change: For areas where agroforestry is especially feasible at lower cost, higher awareness of the potential and benefits could unlock action, which does not necessarily require high capital input expenditure in some contexts. This would require a detailed mapping of agroforestry feasibility in Georgia in order to target campaigns effectively. Land tenure security would also be a pre-requisite for agroforestry in most cases, due to the long-term nature of investments made.

3.2.9 Genetic editing for disease resistance

Measure Global research into genome-editing technologies hopes to open new opportunities to engineer disease resistant traits for modified breeds of crops (Zaidi *et al.*, 2020). Such developments could improve the quality and yield of major crops. By reducing losses, the relative emissions intensity of agricultural yield could be significantly decreased.

Status Genetic editing remains at an early stage of international research and development and is not practiced in Georgia.

Potential In the order of 200 ktCO_2e in 2030: Crop losses currently account for approximately 10-40% of potential crop yields at the global level, depending on the crop type and the climatic events that occur at the local level in any given year. Research into the potential for genetic editing remains at an early stage globally, and is also highly dependent on local climatic and soil conditions. The potential impact for Georgian crops and croplands remains unknown; total emissions from agricultural soils are projected to reach 2.2 MtCO_2e in 2030, so crop losses in the range of 10-40% would account approximately for emissions of 200-900 ktCO_2e.

Costs Unknown: Further international research and development is needed, before meaningful predictions can be made on market supply prices and yield impacts. Costs could be significantly offset by the financial benefits incurred by reduced yield loss. Increased resilience and yield reliability may also decrease costs for insurance services.

Unlocking Research and development: Participation in global research efforts could support an increased understanding on the local suitability of solutions that emerge, and may lead more quickly to the development of more locally appropriate options.

3.2.10 Plant and soil microbiome technology

Measure In recent years, a wave of new research has shed light on the potentially significant relationships between the microbiome of soils and plants and climate change mitigation and adaptation outcomes. The bacteria and fungi that make up these microbiomes determine the quality of soils and their carbon sequestration capacity. They can also influence in different ways how the soil breaks down nitrates and emits nitrous oxide. Interventions to optimise microbiomes could significantly increase carbon sequestration and reduce nitrous oxide emissions from croplands, and perhaps also from pastures. The most accessible method of microbiome engineering is the inoculation of specially created microbiome cocktails – which contain a mixture of positive bacteria and prebiotic feed – into croplands. Further emerging technologies include plant breeding approaches to manipulate microbiomes, and microbial biotechnology approaches for in situ microbiome manipulation via use of biochemical, cellular and genome-editing methods (Hu, He and Singh, 2017).

Status Microbiome cocktails for cropland inoculation have reached the global market, but remain at an early stage of development and are oriented more at the major global cash crop markets; they are not yet used in Georgia. More advanced methods of in-situ cropland microbiome modification have only recently come onto the biochemical engineering research agenda at the global level.

Potential Unknown: Research into the climate change mitigation potential for all methods of microbiome engineering remains at an early stage, and is also highly dependent on local climatic and soil conditions. The potential impact on Georgian soils remains unknown.

Costs High (> 100 USD/tCO_2e): Currently available agricultural inputs for microbiome optimisation would currently be expensive to bring to the Georgian market, while the impacts for climate change mitigation and crop yields on Georgian soil are unknown. It is likely that the maturity, affordability and suitability of these inputs for the Georgian context will increase significantly in the coming decade. The costs of potential biotechnological options for in-situ microbiome manipulation remain unclear, as those measures remain at an early stage of research and development.

Unlocking Research and development: Participation in global research efforts could support an increased understanding on the local suitability of solutions that emerge, and may lead more quickly to the development of more locally appropriate options.

3.2.11 Perennial grain crops

Measure Perennial crops are those which live for multiple years without needing to be replanting after every harvesting season. Recently, new species of perennial wheat-like grains have been discovered or developed. Compared to other crops, perennial cropping leads to less carbon release and soil erosion that may otherwise be caused by tillage, seeding and other soil disturbances. Perennial crops improve soil structure, water retention and carbon sequestration.

Status Georgia is well familiar with traditional perennial crops, with vineyards and orchards accounting for approximately 25% of cropland in 2018, but there is currently no use of new perennial grains in Georgia. New perennial gains are gaining traction at the international level as a high potential climate change mitigation measure, but are not in widespread use in any country. International research efforts are likely to significantly increase the availability of perennial cropping over the next decade.

Potential In the order of 70 ktCO_2e in 2030, assuming a switch to perennial wheat grains from annual what crops, which currently occupy approximately 50,000 hectares of Georgian cropland (Ministry of Agriculture and LTD Georgian Amelioration, 2017). This estimation assumes a similar climate change mitigation impact from other conservation agriculture measures combined; the specific climate change mitigation potential of perennial cropping is still highly uncertain and the subject of international research. The potential could be significantly higher still, if new perennial grains could also replace annual barley and maize crops.

Costs Unknown. Further international research and development is needed, before meaningful predictions can be made on market supply prices and crop yields.

Unlocking Research and development: Participation in global research efforts could support an increased understanding on the local suitability of solutions that emerge, and may lead more quickly to the development of more locally appropriate options.

3.3 Demand side measures

Demand side measures – including the reduction of losses in the value chain and in households, as well as shifting human diets – could improve the efficiency of food systems as well as shifting those systems to less emissions intensive forms of production. At the global level, such measures hold very large potential and will be important to decarbonise the nutritional needs of a growing global population. However, such measures require profound adjustments in human behaviour and are difficult to achieve in the short term. At the national level, for Georgia, improvements with regards to these measures may not make a direct impact to national emissions in the short-term; until demand side measures are implemented at a global level, increased efficiencies for food and agriculture systems in Georgia would likely lead to changes in import and export balances, as producers are able to export more surplus production. As such, these measures may be seen as having a strong economic benefit for strengthening the agricultural export industry in the short-term, while having larger potential for emission reductions within Georgia in the longer-term, as other countries also enact demand-side measures and as agricultural production in Georgia gradually adjusts to the changing demands of the population.

3.3.1 Reduce losses in the value chain

Measure The relative emissions intensity of agricultural produce consumption in Georgia may be reduced by reducing the amount of produce that is lost and wasted throughout the value chain. Significant points of wastage in the value chain include on the site of agricultural production, on the site of food processing industries, transport, retail, and for end users.

Status There are not yet significant coordinated programmes to reduce food loss and waste in Georgia. A survey of Georgian farmers in 2017 found that the major causes for food losses was identified as a lack of awareness among farmers and processors on good agricultural practices and post-harvest management skills, as well as lack of knowledge about new technologies coupled with lack of access to technology (FAO, 2017).

Potential Approximately 500 ktCO_2e in consumption-based emissions: Over one-third of agricultural produce worldwide is wasted (FAO, 2020b). Annual household food waste in Georgia was is estimated at 101 kg per capita in 2014 (Denafas *et al.*, 2014); roughly in line with the global average and the average for the western Asian region (UNEP, 2021). Programmes to reduce losses in the value chain might bring Georgia closer to the average food waste rates of Eastern Europe, Western Europe and East Asia, which are approximately 30-40% lower than in Georgia (UNEP, 2021). This could account for production emissions of approximately 500 ktCO2e, although reduced losses may be more likely to result in increased exports rather than reduced production and emissions, unless other countries also follow similar pathways to reduce food loss and waste.

Costs Low (~1-50 USD/tCO_2e): The costs of value chain losses vary throughout the value chain. Producers and retailers in settings with more extensive large-scale producers may have already optimised losses against efforts and costs, due to their inherent incentive to reduce losses to save costs. However, given that the sector in Georgia is characterised by a large proportion of small-scale farming, this optimisation process may not have been exploited at all parts of the supply chain; many cost-neutral or cost-beneficial measures to reduce losses may still be available. Households stand to make significant cost savings from behavioural improvements that reduce waste, and awareness campaigns to achieve such improvements can be performed at relatively low cost.

Unlocking Education and training: The 2017 survey of value chain losses Georgia concluded that access to education, training and the exchange of best practices are the most important measures, particularly at the household level. Producers and retailers will require regulation or incentives to make further significant improvements. A key recommendation was to adopt a national strategy on food loss and reduction (FAO, 2017).

3.3.2 Shift human diets to less emission-intensive nutrition

Measure The emissions intensity of agricultural production ranges drastically across different foodstuffs. Red meat consumption in particular is associated with far higher emissions. Awareness campaigns can lead to behavioural changes in human diets to reduce meat and diary product consumption can lead to changes in patterns of agricultural production that can significantly reduce emissions.

Status Meat consumption in Georgia increased from 25 kg per capita per year in 2009 to 39 kg per capita in 2018 (Koghuashvili and Ramishvili, 2020), as household spending power has also increased over recent years. This rate still remains significantly below the average for middle- and upper-income countries, but projections are for meat consumption to increase. Currently there are no coordinated awareness programmes that target human diet changes for climate change mitigation. In contrast, some research and policy efforts with a focus on nutritional health are focused on increasing the consumption of meat as a source of necessary protein.

Potential Approximately 200 ktCO_2e in consumption-based emissions in 2030: Data from other regions indicates that dietary choice may account for up to a 20% difference in the amount of meat consumption between countries of a similar income level, region and agricultural supply chain, although it takes a considerable amount of time for such differences to manifest. Over the next ten years, a 10% reduction in meat consumption compared to the projected developments, could account for production emissions of approximately 200 ktCO_2e in 2030 in Georgia, although changes in diets may be more likely to result in changes to agricultural import and export balances, rather than reduced production and domestic emissions. Producers may not be able to easily shift agricultural production and so will be reluctant to do so without very significant long-term demand at the global level.

Costs High (> 100 USD/tCO_2e): Populations can be resistant to campaigns for the reduction of meat and dairy produce consumption; the possible returns of investments are unclear, and it is difficult to leverage private sector support due to resistance from agricultural producers and supply chains to facilitate a shift.

Unlocking Awareness and education: As a first step, awareness campaigns that focus on health and environmental benefits can kick-off behavioural change from specific demographics; beyond this, more financial support will be needed to supply chain actors to support changes in supply chain infrastructure, in order to obtain private sector backing.

3.4 Overview of the spectrum of potential action

Figure 5 provides a summary overview of the 20 potential measures for GHG emission reduction for the agriculture sector evaluated in the previous sections. These measures are mapped, according to the relative abatement costs of those measures and the readiness of technologies and practices in the Georgian context, in order to give an indication of the accessibility and attractiveness of different measures

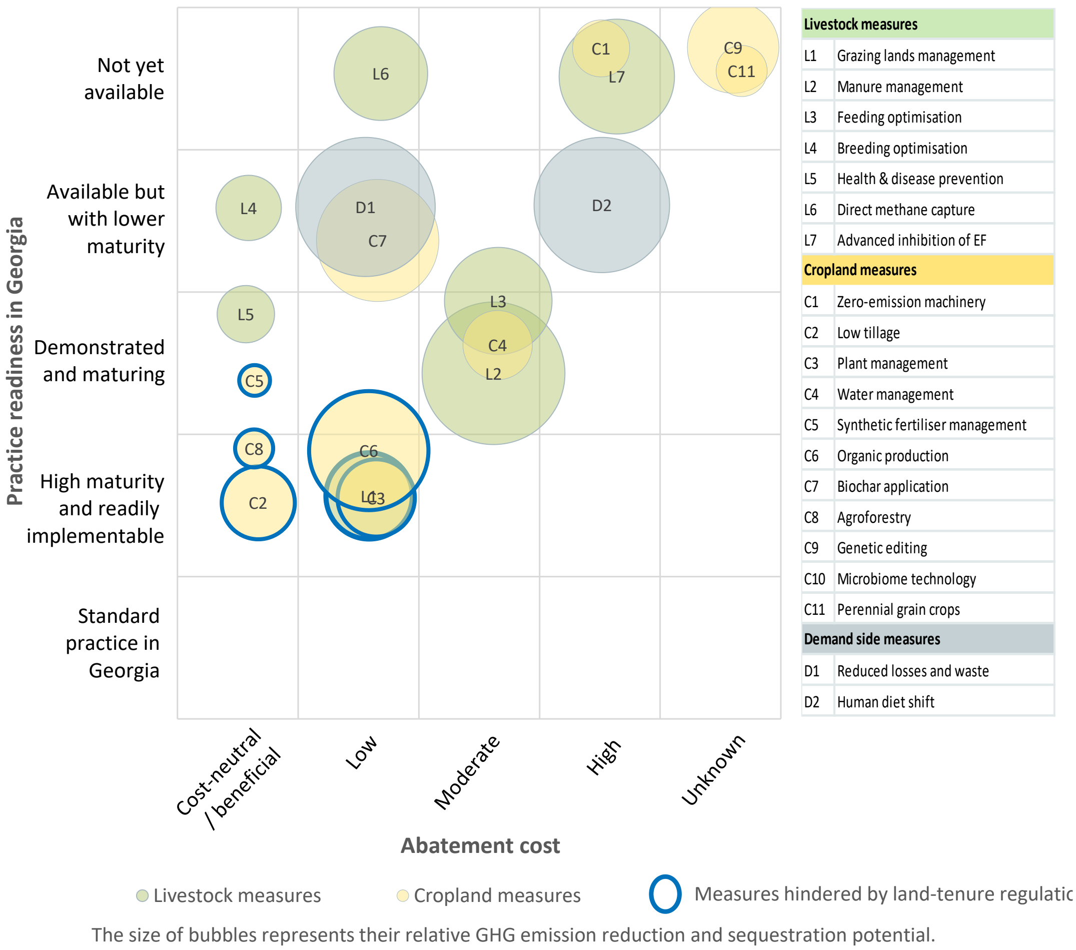


Figure 5: Overview of climate change mitigation potential in the agriculture sector in Georgia. Source: Authors' elaboration based on analysis in sections 3.11-3.33

The overview indicates that none of the 20 GHG emission reduction practices assessed have reached the point of being standard practice in Georgia, despite a large cluster of potential cost-neutral or low-cost actions based on available technologies and practices.

In the **livestock sector**, several areas of mitigation potential with low to moderate abatement costs have not advanced far in the Georgian context, due to lack of finance and regulatory attention. Increased investments are needed to support demonstration projects and scaling up instruments for those measures. Some higher potential measures are foreseeable on the horizon, but depend on the development of new technological solutions at the global level.

For **croplands**, a number of measures which should be relatively accessible in terms of their abatement cost and maturity are hindered by a common barrier in Georgia: unclear land tenure regulations in many areas of the country, especially in rural areas, leads to the situation where land users do not have a strong enough guarantee on their land ownership to invest in sustainable practices that pay-off over the longer-term. In particular, long-term soil quality is undervalued; several measures oriented towards sustainable soil management are overlooked, while increasingly high-input and high-disturbance practices are performed on a season-to-season basis to compensate in the immediate-term for the increasingly degraded quality of the soils that those same practices cause over time. If this barrier would be overcome, and land-users would adopt a longer-term perspective to land management, awareness and education programmes could unlock a wave of action at low cost. A number of more innovative actions for deeper decarbonisation are foreseeable for the future; the mitigation potential of these actions may be very significant, but this remains uncertain due to the early stage of research and development and uncertainty regarding how global solutions will fare in the Georgian context. For some of these more innovative measures in cropping systems, Georgia could benefit from participating in global research programmes, in order to support an increased understanding on the local suitability of solutions that emerge, and to lead more quickly to the development of more locally appropriate options.

Demand side measures – through reduced losses and shifting human dietary patterns – have great potential for emission reductions in agriculture, and may also entail significant benefits for the economy. Realistically, measures to induce these effects are unlikely to have a strong impact for agricultural emissions in Georgia, since change in these areas is very gradual, and any significant changes in consumption and demand are likely to result in changes to Georgia's agricultural import and export balances, rather than a change in domestic agricultural production and associated GHG emissions.

Sections 3.1, 3.2 and 3.3 give a more thorough overview of potential measures for the livestock sector, for cropping systems and for demand side measures, respectively.

4 Financing mitigation actions in agriculture

Agriculture is a sector where sufficient and adequate financing has traditionally been difficult to access. In most developing countries, the share of the financial sector loan portfolio going to agriculture is generally much lower than the sector's share in GDP. Perceived low profitability, high actual and perceived risks and high transaction costs often lead to high interest rates, short terms and tight lending criteria (World Bank Group, no date).

Considering the relative and perceived immaturity of climate related actions, public funds and climate finance are expected to play a large role in attracting and leveraging additional resources.

The global availability of public climate finance is still low, and while section 0 describes some of the most relevant sources, it is worth noting that not enough financing is available globally to implement the necessary measures to decarbonise the global economy. If ambition is to be raised to a level compatible with a 1.5-degree future, developed countries need to increase the availability of finance for developing countries' decarbonisation efforts. Most finance currently available comes from private sources, and has therefore generally higher expectations for returns and shorter payback periods. For this reason, projects that are well designed, successfully leverage private finance with public funding and account for local risks and conditions are better suited to be selected for funding.

4.1 Finance sources

Domestic public funding of agriculture is not generally focused on climate performance or implementation of new processes and technologies, but rather maintaining production and supporting economic development of rural areas. In Georgia, public spending for agricultural sector development amounts to 2.3% of total government spending. This spending happens mostly in grants, purchase of goods and services and "other current expenditures" such as property expenses, premiums, fees, insurance claims and standardised guarantees (the World Bank Group, 2020). It is also focused on the largest agricultural regions with higher wine production. As shown in Figure 6, when compared to other countries in the region, this spending is rather low, especially when considering the contribution the sector makes to the country's GDP.

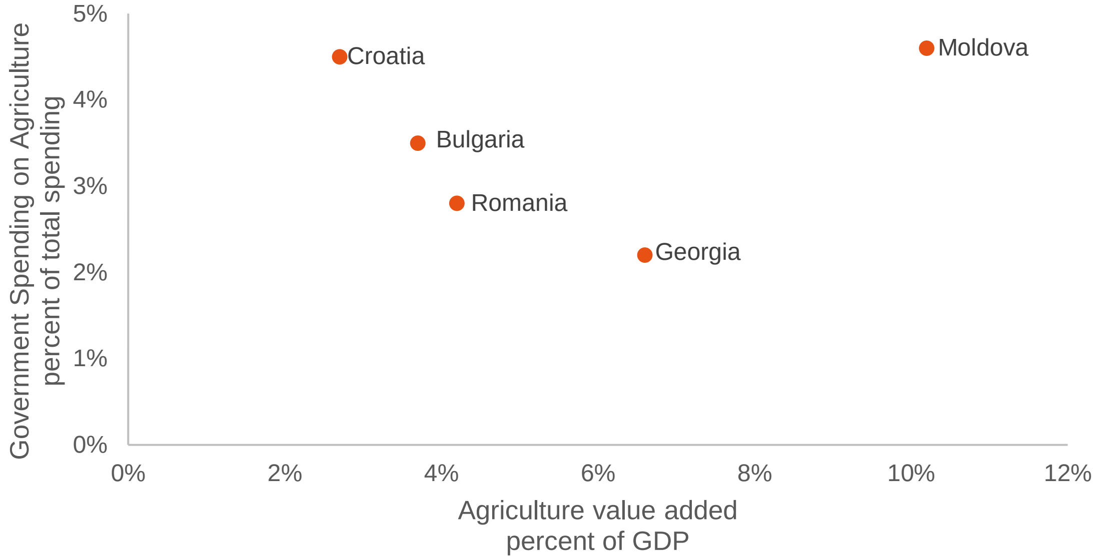


Figure 6. Agricultural value-added and spending in the region in 2017. Source: FAO, GeoStat (the World Bank Group, 2020)

Due to limited public spending on agriculture in Georgia, it may not be expected that many of the measures laid out in Section 3 are financed by the domestic public sector, and local private lenders are currently unlikely to accept the (perceived) risk associated with many of them. Climate-related agriculture measures will require the involvement of the international public and private sectors, and specifically climate finance sources to achieve significant emission reductions in the agriculture sector and enhance the ambition of the NDC. A general overview of finance sources is shown in Figure 7, and public international sources will be further explored in Section 4.4.

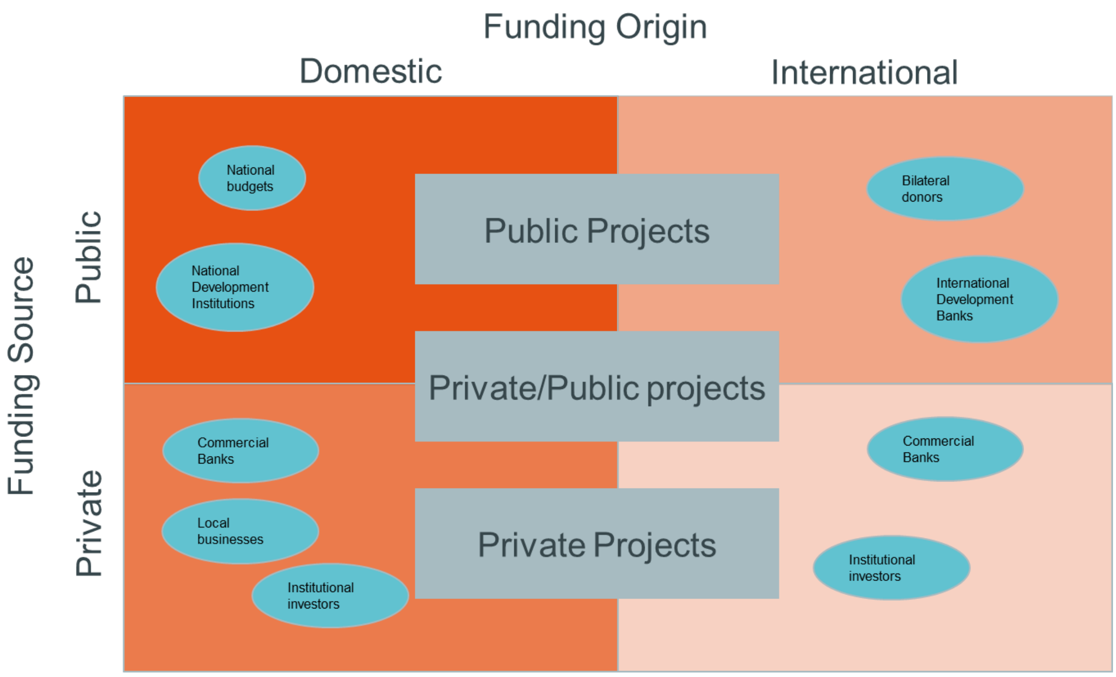


Figure 7. Overview of finance sources and funding origins

Table 2 provides an overview of the basic forms of climate finance traditionally available. The links between these financing mechanisms and the potential measures available in Georgia is explored in the following sections.

Table 2. Overview of climate finance forms

Climate finance mechanism	Description	Examples
Grants	Non-repayable funds given by one entity to facilitate a goal or incentivise performance	• Technology grant scheme
Loans	Amount of finance repayable in a specific time frame with a given interest rate. Combination of loans can be made, with loans having a senior (ensures first repayment, carries less risk) or subordinate (gets paid last, higher returns but higher risk) positions.	• Zero interest loans • Low-cost, concessional loans • Market-rate loans
Guarantees	Risk reduction tool. Guarantees can cover losses in case a project incurs in non-payment, poor performance, etc.	• Insurance policies • Project-related guarantees
Equity	Amount of capital that gives the finance source ownership in the project.	• Balance sheet financing • Project-level equity
Performance-based mechanisms and policy interventions	Mechanisms, normally implemented at the domestic level, that provide financial incentives or create a market for transactions for certain desired outcomes.	• Fiscal/financial incentives such as subsidies, special taxes, Feed-in tariff • Market-based instruments such as GHG emission allowances
Technical assistance	In kind contributions as funding for consultants or topic experts	• Capacity building • Institutional support • Regulatory change • R&D

Source: Authors' own elaboration

4.2 Status and financing needs of measures

Many factors determine the way a project is financed. Proven technologies in established markets that present low investment risks and relatively safe returns can be financed by private investors or businesses directly. On the other hand, new technologies that are perceived as riskier might require public funding with no return expectations in order to demonstrate their potential for wider implementation. In between these two extremes, different measures with risk profiles can be implemented using different financing sources, including combinations of public and private funding.**Error! Reference source not found.** provides an overview of the different stages of technology m aturity or project readiness and the roles that private and public (including climate finance) sources can play in their implementation.

Table 3: Project development stages and financing options (adapted from World Economic Forum, 2019)

Stage	Description	Private sector role	Public sector /climate finance role	Financing options
Preparing	New technologies, feasibility exercises	Low. High risk that the project will not happen. Seed or venture capital for R&D	Upfront costs to reduce uncertainty, increase transparency and build project pipeline	Grants, repayable grants or highly flexible loans
Pioneering	Early-stage projects. Not necessarily commercially viable, although promising. High risk and high transaction costs	Seed or venture capital to test new ideas/markets/business models	Little to no return expectations. Reduce risk or provide advisory services	Grants, repayable grants, concessional loans, junior equity, flexible debt
Facilitating	Low returns relative to risks. Not necessarily viable for private investors only	Returns below commercial rates, investment only with risk lowering instruments	Subordinate position with higher risk, low-cost leverage to enable private capital to meet risk-return thresholds	Equity, flexible debt
Anchoring	Known technology, still high perceived risk	Macro or sectoral risks, but market exists and technology and returns are viable	Can provide funding on similar terms as private investors to provide comfort, act as "stamp of approval" and help "crowd-in" private funds	Concessional or market rate debt, equity
Transitioning	Move funding pools looking to invest in development into a pipeline of sizeable/scalable projects that fit investor requirements	Increase local market knowledge or pipeline, improve inefficient markets	Low, but involvement can provide certainty to private investors	Market rate debt, equity

Figure 5 in section 3.44 evaluated all measures based on the readiness of the practice in Georgia and its emission abatement costs. Project development stages closely relate to practice readiness, considering that financing opportunities improve as a technology becomes better known. For this analysis, we consider the technology readiness a good proxy for investment risk. Similarly, abatement cost can be considered in climate finance as a proxy for project returns, considering that some of the mechanisms used do not expect high (if any) returns, but are rather interested in the climate impact of their investments.

Figure 8 shows the areas where the intersection of practice readiness and abatement costs relates to the project development stages explained in Table 3. Unknown or unavailable technologies with high abatement costs are unlikely to be implemented by private investors and are therefore more suitable to "pioneering" finance, namely technical assistance, grants and seed funding. Measures that might be more common practice but are currently cost prohibitive could then benefit from "facilitating" mechanisms, such as climate finance taking a larger portion of the risk in the form of subordinate debt or junior equity. "Anchoring" mechanisms can help the measures with promising abatement costs that need further (regional) exposure to lower the perceived risks and attract the interest of a broader set of investors. Once implemented, technologies that fit the country's needs and circumstances and deliver the expected returns can gradually "transition" towards the bottom-left corner of the diagram and become standard practices that offer low abatement costs. These measures should be the first to be implemented as part of the country's NDC and ideally would not require concessional or climate funding.

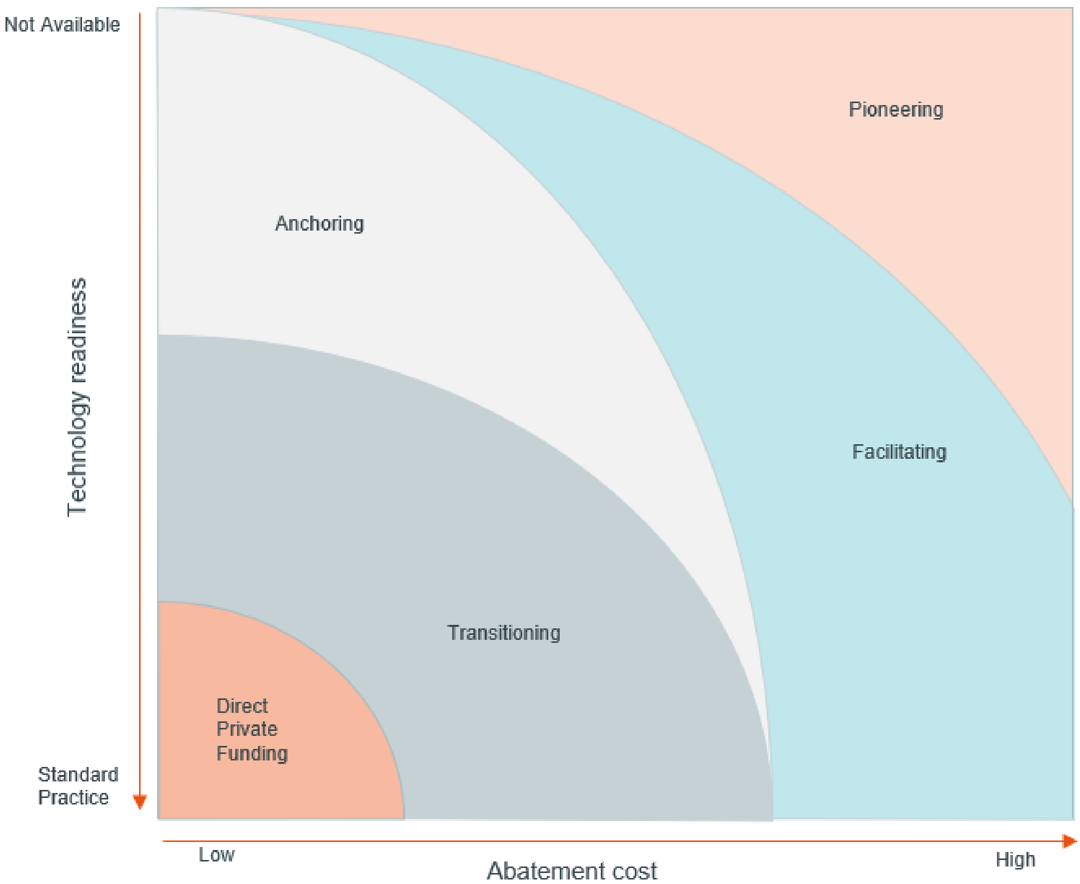


Figure 8. Project development stages

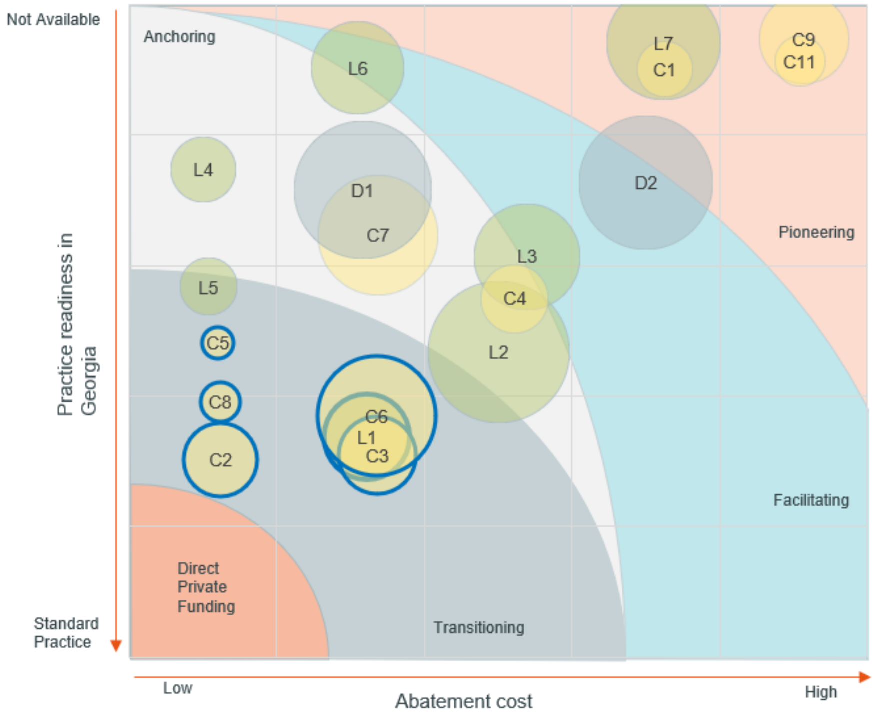
4.3 Financing agriculture in Georgia

The different measures presented in Section 3 can be categorised within the project stages described in Section 4.2 to make an initial assessment of their financial needs, as shown in Figure 9.

This is a simplified concept that only partially considers additional, non-financial barriers. For example, awareness of improved processes might be low and many measures could benefit from improved training for small scale farmers on climate-smart production measures. Small scale farmers with no financial capacity to take on new loans, or with low appetite for innovation might not be interested in changing their practices to climate-smart ones. While these barriers have been considered when assessing the practice readiness in Georgia, it is worth noting that solving the financing question will not automatically lead to their implementation.

A widespread issue hindering the uptake of mid to long term improvements in agriculture is land ownership uncertainty. As it is seen in Figure 9, all measures that seem to be ready for transitioning into common practice and therefore more easily financed by commercial and domestic means are affected by this issue and therefore need unlocking activities beyond financing (the measures affected are identified with a blue border). Policy activities that provide certainty to farmers and investors are necessary to reach more widespread implementation and achieve their potential emission reductions.

Figure 9 provides an indicative overview of the mitigation potential of each measure and its project development stage, while Figure 10 provides an indicative suggestion of the financing mechanisms suitable for each measure according to its project development stage



Livestock measures	
L1	Grazing lands management
L2	Manure management
L3	Feeding optimisation
L4	Breeding optimisation
L5	Health & disease prevention
L6	Direct methane capture
L7	Advanced inhibition of EF
Cropland measures	
C1	Zero-emission machinery
C2	Low tillage
C3	Plant management
C4	Water management
C5	Synthetic fertiliser management
C6	Organic production
C7	Biochar application
C8	Agroforestry
C9	Genetic editing
C10	Microbiome technology
C11	Perennial grain crops
Demand side measures	
D1	Reduced losses and waste
D2	Human diet shift

Figure 9. Development stage and mitigation potential of the described measures

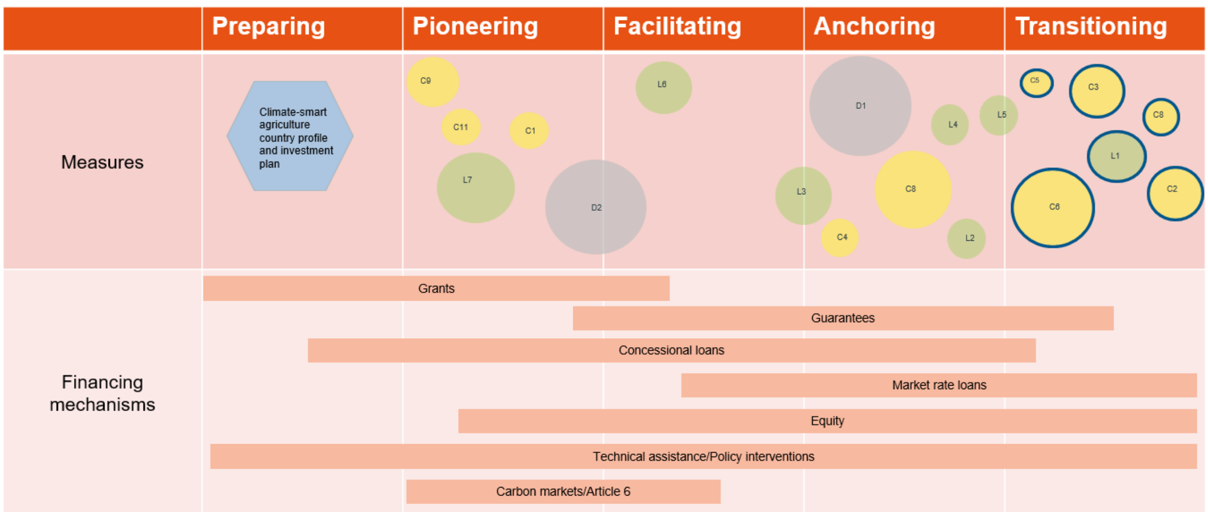


Figure 10. Agriculture measures at their corresponding development stages, and the potentially suitable financing mechanisms for their implementation.

4.4 Potential climate finance sources for Georgia

To successfully implement the measures described, a wide range of climate finance sources are available. This section aims to describe some of them, as well as the mechanisms they offer and some relevant examples of current or past projects. The list is not exhaustive but aims to briefly describe the most relevant sources and give an indication of the next steps necessary for their engagement.

Matching measures with finance sources mostly depend on the project needs, but should also account for funding cycles, changing priorities (both geographical or sectoral) and other factors. It also often requires a combination of sources and mechanisms, whether they all come from the same donors or from a variety of them. Project support usually use several mechanisms that include grants for preparation or technical assistance as well as loans, guarantees or equity to jump start investment.

Sources differ in origin, as seen in Section 4.1, with some funds looking to finance projects with the primary objective of reducing emissions, while others focus on economic and social development but welcome environmental and climate benefits. The funds that are linked to the UNFCCC tend to have a strong climate focus, while multi- or bilateral funding might have other priorities. Multilateral development banks have pledged to increase the share of finance for climate-related projects, so having a strong rationale for emissions reductions can still be an important consideration for accessing non-climate specific funding.

Due to their relevance for the Georgian context, a general description of finance sources is made below, identifying them as funds linked to the UNFCCC, multilateral banks, bilateral donors and finally insights are provided into potential financing through carbon markets or the Paris Agreement's Article 6 mechanism.

In many cases, the funds linked to the UNFCCC (GCF, GEF and AF) deliver their support through multilateral development banks or other donor organisations, therefore having different financing components and falling into more than one of the examples below.

Climate-specific funds linked to the UNFCCC

Green Climate Fund (GCF)	
Description	The GCF was created from the UNFCCC climate negotiations as the main financing arm for ambitious and transformative projects for climate change mitigation and adaptation.
Type of support available	The GCF finances projects over four stages of development 1. Transformational planning and programming: by promoting integrated strategies, planning and policymaking to maximise the co-benefits between mitigation, adaptation and sustainable development. 2. Catalysing climate innovation: by investing in new technologies, business models, and practices to establish a proof of concept. 3. De-risking investment to mobilize finance at scale: by using scarce public resources to improve the risk-reward profile of low emission climate resilient investment and crowd-in private finance. 4. Mainstreaming climate risks and opportunities into investment decision-making to align finance with sustainable development: by promoting methodologies, standards and practices that foster new norms and values.
Relevant current/ past projects in agriculture	- A risk sharing facility that targets agricultural MSMEs that demonstrate environmentally sustainable practices in Mexico and Guatemala ($30M in loans, equity, guarantees and grants). - $25M in grants to promote climate resilient agricultural practices, integrate climate change risk data into water and land management to support smallholders, and reduce the risk and impact of climate change-induced landslides during extreme events that disrupt market access in Bhutan - $10M in Niger (70% in loans and 30% in grants) to incentivise the participation of the private sector by engaging with commercial banks and microfinance institutions to provide financial support to smallholder farmers by increasing access to credit in tandem with technical assistance and capacity building.
Current involvement in Georgia	The GCF has four active projects in Georgia with $107.1M in total financing. It also funds four Readiness activities with $845k in approved funding to strengthen capacities at the Nationally Designated Authority (NDA) and support national planning and project identification. Active projects include: - $27M grant for scaling up of Georgia's Multi-Hazard Early Warning System and improve climate information. - $38M grant for forest sector reform to enhance carbon sequestration through the introduction of sustainable forest management. It will increase the uptake of energy efficient stoves through an innovative combination of market development, along with technical and financial assistance to local stove and alternative fuel producers and customers. - A $378M regional project ($344M in loans and $34M in grants) to provide co-financing for climate-related projects through private sector Partner Financial Institutions (PFIs). Projects across industrial, commercial, residential, transport and agricultural sectors from 10 countries in the region are eligible for support. The GCF also has provided Georgia with "readiness" funding to improve local capacities related to adaptation planning and develop strategic frameworks to engage with the fund.
Overview of application/ financing process	Funding proposals are usually developed in cooperation with the GCF Secretariat. Proposals must be presented to the GCF Board through an Accredited Entity and have the endorsement of the Nationally Designated Authority (NDA), in this case the Ministry of Environmental Protection and Agriculture. The board can evaluate and approve projects in each of the four annual board meetings.

Global Environment Facility (GEF)	
Description	Established in the eve of the 1992 Rio Earth Summit, the GEF aims to tackle the most pressing environmental problems. It serves as a financial mechanism to five conventions: the UNFCCC, the Convention on Biological Diversity, the Stockholm Convention on Persistent Organic Pollutants, UN Convention to Combat Desertification, and Minamata Convention on Mercury.
Type of support available	The GEF delivers grants through implementing agencies, often with a co-financing amount from other organisations.
Relevant current /past projects in agriculture	- $1.5M grant (and $50k project preparation grant) with $8M in cofinancing for promoting climate smart livestock management in the Dominican Republic - $3.5M grant with $15M cofinancing for climate smart agriculture alternatives for upland production systems in Lao PDR
Current involvement in Georgia	Over the years, the GEF has provided over $39M in grants (with $195M in cofinancing) for 29 projects in Georgia. Additional benefits have been received through regional or global projects. There are currently 13 approved projects in different stages of execution, including: - A $5.3M grant with $27.5M cofinancing implemented by IFAD for Enhancing Resilience of Agricultural Sector in Georgia (ERASIG) - A $1.8M grant with $12.2M cofinancing for Achieving Land Degradation Neutrality Targets of Georgia through Restoration and Sustainable Management of Degraded Pasturelands - A $1.5M grant with $4.8M cofinancing for Generating Economic and Environmental Benefits from Sustainable Land Management for Vulnerable Rural Communities of Georgia
Overview of application/ financing process	Funding from the GEF is accessed through the implementation agencies. In Georgia these are the Food and Agriculture Organisation (FAO), the International Fund for Agricultural Development (IFAD), the World Bank, the UN Development Programme (UNDP), the UN Environment Programme (UNEP) and the UN Industrial Development Organisation (UNIDO). Funding should be requested by the national government's Operational Focal Point (the Ministry of Environmental Protection and Agriculture) through one of these agencies.

Adaptation Fund (AF)	
Description	A Fund established at COP7 in Marrakesh in 2001 to finance concrete adaptation projects and programmes in developing countries that are particularly vulnerable to the adverse effects of climate change.
Type of support available	The AF mostly delivers grants that support communities adapt to climate change. These can be in the form of innovation grants, readiness grants, or enhanced direct access grants.
Relevant current /past projects in agriculture	- $14M grant in a regional project in West Africa to promote Climate Smart Agriculture - $7.8M grant in Lebanon for enhancing adaptive capacity of rural communities through climate smart agriculture.
Current involvement in Georgia	- $4.3M grant for the adaptation component of a project looking to modernise and improve the market access of the Georgian dairy sector - A completed project that delivered $5.3M grant to develop climate resilient flood and flash flood management practices for vulnerable communities
Overview of application/financing process	As for the GEF and GCF, funding is channelled through accredited entities and submission needs the approval of the national designated authority, also the Ministry of Environmental Protection and Agriculture. The AF partners with the Climate Technology Centre and Network (CTCN), which can provide technical assistance during the project preparation phase.

Multilateral Development Institutions with climate-related funding

The World Bank	
Description	The World Bank was created in 1944 to support the reconstruction after World War II. It is composed by several institutions and hosts a number of funds, including the GEF and the Climate Investment Fund (CIF).
Type of support available	The World Bank Group provides a wide range of support through its different modalities: IBRD provides financial development and policy financing, IDA provides zero-to low-interest loans and grants, IFC mobilizes private sector investment and provides advice and MIGA provides political risk insurance (guarantees). It can finance infrastructure, policy development or provide grants for developing and scaling productive activities.
Relevant current /past projects in agriculture	- $500M loan to support the development of an environmentally sustainable, inclusive, and competitive beef production in Kazakhstan - $80M to strengthen rural market linkages and entrepreneurship ecosystem and to create job opportunities in Nepal
Current involvement in Georgia	- $80M loan (with an additional $100M from the Asian Infrastructure Investment Bank) for prevention, detection and response to the COVID-19 pandemic - $20.4M for improving delivery of the irrigation and drainage services in selected areas; and develop improved policies, procedures, and systems as a basis for a national land management program
Overview of application/financing process	Engagement with the Bank is best done through the local office, as it is the place that coordinates the support to the country. While support can be given through different entities or organisations, all funding is requested through the Georgian Ministry of Finance.

International Fund for Agriculture and Development (IFAD)	
Description	A Fund specialised in rural environments and agriculture, IFAD is an international financial institution and a specialized agency of the United Nations dedicated to eradicating poverty and hunger in rural areas of developing countries.
Type of support available	Grants and loans for rural development through its many initiatives. IFAD aims to improve all sectors within rural areas including livestock, crops, water, fisheries, nutrition, among others.
Relevant current /past projects in agriculture	- A $24.3M loan to Support Pastoral and Agro-Pastoral Development in Tanzania to improve livestock production through research and technology, as well as marketing systems and infrastructure for livestock products. - A $21.3M loan (supported by $10M from OPEC, $5.3M from the GEF and $11.2M from AFD) to improve food security, nutrition and resilience of smallholder farmers to climate change in The Gambia.
Current involvement in Georgia	IFAD has a Country Strategy Program (COSOP) in Georgia, with activities that include promoting investments by smallholder farmers and agribusiness to foster competitive climate-smart value chains; improving access for farmers and agribusinesses to key markets (particularly through better access to credit, savings, leasing and insurance); and promoting financially and environmentally sustainable rural economic infrastructure to improve productivity, post-harvest management and the resilience of smallholder producers. Current projects are: - $13.3M loan (and $5.3M grant from the GEF) for the Agriculture Modernization, Market Access and Resilience Project, which aims to raise the incomes of smallholder farmers and increase their climate resilience. It does this through public and private investments in upgrading climate-proof productive infrastructure, enterprises and smallholder farmer production systems and technologies in support of inclusive growth of climate smart agricultural value chains - $18.2M loan (and $4.3M grant from the AF) for the Dairy Modernisation and Market Access Project to support smallholder producers with know-how and technologies to upgrade their milk production systems, adopt food safety standards and comply with the food hygiene regulations.
Overview of application/financing process	IFAD's involvement is usually defined in the country's COSOP. In order to expand the scope of this document, consultation with IFAD through the country's counterpart is necessary, in this case the Ministry of Environmental Protection and Agriculture.

Asian Development Bank (ADB)	
Description	Established in 1966, the ADB is owned by 68 member countries—49 of which are from the Asian region. It looks to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty.
Type of support available	ADB's efforts and strategy to achieve food security in the region emphasizes the integration of agricultural productivity, market connectivity, and resilience against shocks and climate change impacts as the three pillars to achieve sustainable food security. As other MDBs, it provides loans, grants, equity investments and guarantees.
Relevant current /past projects in agriculture	- A $20M grant for Climate-Resilient Livestock Value Chain Development in Tajikistan - A $300k technical assistance grant for Green Farmland Construction and Agricultural High-Quality Development in the Yellow River Basin in China - A $400M loan for a Competitive and Inclusive Agriculture Development Program in the Philippines.
Current involvement in Georgia	- A $900k technical assistance grant to support sector reforms and prepare the Water Resources Sector Development Program - A $2.55 technical assistance grant (for Georgia and 9 other countries in the region) to improve social safeguards, in particular around land issues such as acquisition and resettlement (LAR) performance. - A $4M loan to Credo Bank JSC to support agricultural micro, small and medium-sized enterprises (MSMEs), low-income farm households, women-owned MSMEs, and agri-tourism in Georgia.
Overview of application/financing process	For its engagement with Georgia, the ADB has developed a Country Partnership Strategy (2019-2023) and a Country Operations Business Plan (2021-2023). The Ministry of Finance is the main counterpart in the country.

European Bank for Reconstruction and Development (EBRD)	
Description	Created in 1991, the EBRD is owned by 70 countries, as well as the European Union and the European Investment Bank. It strives to develop a healthy investment climate and promote environmentally and socially sound and sustainable development. The EBRD is active in about 40 countries across the Southern and Eastern Mediterranean, Central and Eastern Europe, and Central Asia.
Type of support available	Agribusiness is one of EBRD's key priority sectors, with a dedicated "Agribusiness Strategy 2019-2023". It aims at achieving food security, preserving natural resources, and improving the social and environmental impacts of the sector. As other MDBs, EBRD provides loans, equity investments and guarantees with a focus on the private sector.
Relevant current /past projects in agriculture	- A $30M loan for climate risk assessment and development of a corporate climate strategy for a grain seeds exporter and producer in Ukraine. - A $60M loan for a sustainable transformation of the cotton farming sector in Uzbekistan, including improved irrigation systems and fertiliser use. - A $30M loan for expanding and promoting organic and sustainable agricultural practices in Lithuania, Latvia and Estonia.
Current involvement in Georgia	- A $83M loan to the City of Tbilisi for the acquisition of a new bus fleet, replacing outdated polluting buses. - A $40M loan for introducing comprehensive energy efficiency renovations of public buildings, building the capacity of local construction companies in this sector and supporting the creation of a value chain of green technologies.
Overview of application/financing process	For its engagement with Georgia, the EBRD has approved its latest "Strategy for Georgia" in 2016. Applications for financing typically go through the local partner finance institutions of EBRD. The EBRD may also provide direct financing and support for SMEs through a number of loan and equity facilities.

Bilateral Development Funding

Developed countries often have their own international development agencies and provide developing countries with funding to work in specific sectors. They mostly provide grants and technical assistance to support implementation of governments´ priorities. While traditionally more focused on economic development, a larger focus has been given to climate-related issues in recent years. The following provides an overview of the most important actors in Georgia while the table below provides a few concrete examples of bilateral development projects.

While not a financial institution, the **European Union** provides development funding for Georgia through its European Neighbourhood Instrument (ENI), which aims at improving the quality of life of ordinary Georgians in a tangible and visible manner and provides over €120 million to Georgia annually in grant assistance.

The **United States** are an important donor for bilateral development finance in Georgia through its development agency USAID. USAID began operating in Georgia in 1992 and has since then provided close to $2 billion in assistance to Georgia, and today dedicates approximately $40M annually to different projects that focus on economic growth, developing democratic institutions, enhancing energy security, and mitigating climate change. The engagement in Georgia is guided by the ‘Country Development Cooperation Strategy - Georgia 2020-2025’. One of its current programmes implemented together with Cultivating New Frontiers in Agriculture (CNFA) is specifically focused on the development of the Georgian Agriculture sector (see Table below).

Germany is another of the largest donors for bilateral development projects in Georgia. The German development bank KfW began its activities in Georgia, on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), in 1993 with investments in the energy, financial, municipal, environment and health sectors. Today KfW is one of largest donors in the areas of biodiversity and natural resources in the Southern Caucasus and an important donor for the Georgian energy sector. Germany is further providing technical assistance through its development agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Most of its work is commissioned by Germany's Federal Ministry for Economic Cooperation and Development (BMZ), Federal Ministry for the Environment (BMU) or the Federal Ministry for Economic Affairs and Energy (BMWi). GIZ´s core competency is capacity development. It supports people to become specialists and advises governments on how to achieve objectives and implement nationwide change processes by incorporating them into legislation and strategies. Most of its support to international governments is given through grants and technical assistance.

France’s Agence Française de Développement (AFD) funds, supports and accelerates the transition to a fairer and more sustainable world. It focuses on climate, biodiversity, peace, education, urban development, health and governance. As a public financial institution, AFD offers many financial products depending on the type of project and the recipient. It provides loans, grants, guarantees, debt reduction tools, and participates in several initiatives to support sustainable development in developing countries. Agreenfi is AFD’s agricultural and rural finance label. It promotes the mobilization of financial institutions in emerging countries to achieve productive and resilient agriculture, improve living conditions for rural populations and foster the sustainable structuring of rural territories. It aims to provide actors in rural areas in developing and emerging countries with access to appropriate and sustainable financial services, as well as customized technical assistance. In Georgia, AFD is currently involved in the Modernization of Georgia's Water Supply and Sanitation System. It provides a €58M credit line supported by a €7.15M grant from the EU.

Further bilateral donors in Georgia include but are not limited to the Chinese Development Bank (CDB), the Swedish International Development Cooperation Agency (SIDA) or the Norwegian Agency for Development Cooperation (Nirad).

Project examples in Georgia		
European Union/ ENI	-	As part of this funding, the EU provides support to agriculture and rural development in Georgia through the European Neighbourhood Programme for Agriculture and Rural Development (**ENPARD**), implemented since 2013 with a total volume of €230M. The main goal of ENPARD is to reduce rural poverty, through the provision of technical and financial assistance to the government and NGOs working directly with communities on the ground.
Germany/ GIZ	-	Capacity development for climate policy in the countries of South-East and Eastern Europe, the South Caucasus and Central Asia, Phase III (**CDCPIII**). This third phase of the CDCP project supports political decision-makers and other responsible institutions to systematically plan and successfully implement integrated, ambitious climate policy
	-	Management of natural resources and safeguarding of ecosystem services for sustainable rural development in the South Caucasus (**ECOserve**). Promotes sustainable and biodiversity-friendly use of natural resources in land-use systems, considering land cover percentage, need for protection, safeguarding the rural population's livelihood source, and the government's priorities.
USA/ USAID	-	The **Georgia Agriculture Program** is a five-year programme that together with key Government ministries and an array of private sector partners invests to increase production capacity, efficiency, and compliance with international standards of quality. USAID assistance enables producers and processors to add value through modern production, processing, storage, and distribution techniques, while building regional and international market linkages, and creating high-value jobs in rural Georgia.

Impact Investors

Impact investing refers to investments "made into companies, organizations, and funds with the intention to generate a measurable, beneficial social or environmental impact alongside a financial return" (The Global Impact Investing Network, 2017). This type of investing is usually made by funds that receive capital from both public and private funds, and have different levels of return for each, allowing them to lower the risk of investments and attract larger amounts of private institutional funds. These funds are then invested via intermediaries promoting green finance (usually local financing institutions) or directly in businesses pursuing sustainable practices. While these are private investors, overall returns are usually expected to below market rate, making impact in Environment, Social and Governance (ESG) metrics the priority.

Examples of impact investment in agriculture can be found all over the world, and include loans and technical assistance to small agribusinesses that operate as aggregators and buy from small-scale producers in their communities, mortgage finance for expansion of organic/sustainable farming and agroforestry, and private equity/venture capital for technical solutions targeting water management and irrigation, seed treatment, soil amendments, alternative protein products, indoor agriculture, methane capture anaerobic digestion and food waste solutions (Lang, Humphreys and Rodinciuc, 2017).

Impact investment in agriculture has increased in the last years but is not yet widely active in Georgia. Many of the measures described in this study have been supported by impact investors globally (e.g. organic farming, smart irrigation, biowaste/manure management) so proactively seeking this kind of funders could open the door for financing, especially for small farmers.

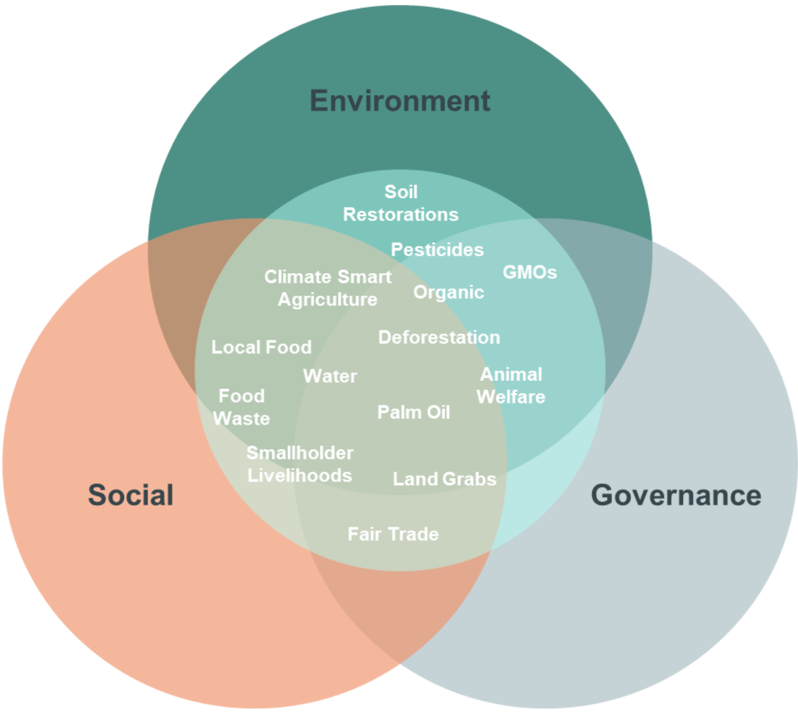


Figure 11. Leading ESG Investment themes in Agriculture. (Lang, Humphreys and Rodinciuc, 2017)

Carbon Markets under the Paris Agreement's Article 6

Even though the rules for the Paris Agreement's Article 6 have not been agreed on, countries are starting to develop a strategy to engage in a potential market for Internationally Transferred Mitigation Outcomes (ITMOs). This concept would follow the Clean Development Mechanism (CDM) as the main market mechanism linked to the UNFCCC negotiation process to address global emissions.

As all countries have now committed to domestic emission reduction targets under the Paris Agreement, countries may consider reserving the use of market mechanisms such as ITMOs for technologies with higher abatement costs (and therefore only mentioned under the *pioneering* and *facilitating* stages in Figure 8) that would not be implemented as part of countries' unconditional portion of the NDC. While some countries have started signing bilateral agreements to cooperate under the PA's Article 6 framework, some factors should be considered:

- Under the CDM, purchasing countries were interested in low-cost mitigation projects. Now that all countries have committed to reduce their own emissions, seller countries should focus on receiving support for some of the more difficult (expensive) measures to implement.
- Countries are expected to increase ambition every five years as they update their NDCs under the ambition ratchet mechanism. If transferred to other countries, mitigation outcomes from newly integrated sectors or measures could not count towards the country's new reduction targets.

It is therefore recommended that international climate finance is sought for the implementation of mitigation projects, ideally without transferring these outcomes. New trends in corporate strategies are already taking this voluntary approach and are willing to make donations for the deployment of emission-reducing technologies (NewClimate Institute, 2020; WWF and BCG, 2020). This could become an interesting source of funding for Georgia, and although it is not yet widespread, it is likely to become more available if countries on the receiving end proactively seek this kind of finance. If an agreement is to be made to transfer outcomes, it should be for high-cost measures considered a "high-hanging fruit" that promote a real technology transfer in Georgia.

4.5 Next steps to access climate finance sources

As a general recommendation, the more specific knowledge there is about a specific activity, the easier it will be to design strategies for its implementation. This report presents 20 agricultural practices with the potential to reduce GHG emissions in Georgia, as well as an overview of the finance sources that could be use for their implementation. As mentioned earlier in this section, the level of climate finance available is still too low to meaningfully decarbonise the global economy and competition for funding is high. For projects to be eligible to receive financing, detailed preparation is needed to successfully access highly sought-after funding.

As shown in the analysis, a number of policy measures need to be taken in order to unlock many of the most promising measures. Land ownership, financial literacy and access to finance are some of the issues that need to be addressed to fully unlock the potential of emission reductions in the agriculture sector. This can be done domestically and unilaterally while also be supported by technical assistance components in grants from bilateral development agencies or in loans by multilateral finance institutions.

In parallel, a strategy can be developed that groups initiative per project stage (as seen in Figure 8) and prioritises the measures more feasible to be implemented. This can eventually develop into an investment plan that carefully considers the climate change impacts the local conditions and sets targets for each measure, prioritising the practices, programs and policies to be implemented, creating a Climate-Smart Agriculture investment portfolio, that can be made available to finance providers to select the measures that better align with their interests or priorities.

5 Benefits of decarbonisation in the agriculture sector

This section explores the extent to which there are synergies between mitigation action in the agriculture sector and other major national strategic and development priorities in Georgia.

Two key overarching national strategic and development priorities in Georgia are the EU Association Agreement and the Sustainable Development Goals (SDGs) of Agenda 2030. The synergies between these strategic priorities and decarbonisation pathways for the agriculture sector are presented in the following sub-sections.

5.1 Synergies with the EU Association Agreement

EU-Georgia Association Agreement and Energy Community Treaty

An Association Agreement between the European Union and Georgia was signed in June 2014 and fully entered into force in July 2016. **The Association Agreement aims to provide a framework that allows for deeper political and economic relationships between the EU and Georgia**, including through the increased alignment of some key regulations and standards. In addition to the Association Agreement, **Georgia acceded to the Energy Community Treaty in June 2017, which seeks to liberalise and align energy markets** with those of the EU Member States and other Energy Community Parties.

Compliance with the Association Agreement and the Energy Community Treaty has particularly high political priority in Georgia, since the European Union is viewed as a key strategic partner, and since closer ties to the EU customs union and even to the EU membership process are consistently sought by the Government of Georgia in recent years. Thorough implementation of the Association Agreement and the Energy Community Treaty is understood to be a condition and potential vehicle for further developments in the EU-Georgia partnership.

The 2014 Association Agreement and the 2017 Protocol for the Energy Community Treaty commit Georgia to an ambitious reform agenda through the identification of a list of European Commission Directives for implementation in Georgia, with a timetable of implementation for each. Several of the identified Directives are relevant for the agriculture sector, while others refer more broadly to the energy sector and other aspects of environmental protection.

As part of the Association Agreement, the **EU and Georgia have agreed to cooperate on issues regarding agriculture and climate change**. Georgia aims to harmonize its legislation regarding agriculture, rural development and climate action with that of the EU.

In exchange, the EU has agreed to support Georgia in shaping the modernization and increasing the sustainability of its agricultural production, improving both competitiveness and efficiency of Georgia's agricultural sector. **Article 332 and Article 333 of the Association Agreement establish the cooperation on issues regarding agriculture and rural development.**

5.2 Synergies with other national planning documents

Third National Environmental Action Programme (NEAP-3) of Georgia 2017-2021

NEAP-3 identifies the environmental priorities of Georgia and establishes the strategic long-term goals, targets and activities required to improve the environment for the 5-year period. The ultimate objective of the environmental policy, upon which the NEAP-3 is built, is sustainable, balanced development where the quality of the environment is considered equally along with all the socio-economic challenges.

The agriculture measures presented in this chapter will support the implementation of strategic objective 1, as well as the climate change goals and targets. Strategic objective 1 covers the improvement of the status of the environment, the protection and sustainable use of natural resources and minimising risks to human health.

The main problems related to agriculture are the unsustainable use of water for irrigation and diffuse pollution caused by runoffs from land (nitrates, phosphates and pesticides), which will be addressed by the proposed measures.

Rural and Agricultural Development Strategy of Georgia – 2021-2027

The strategy outlines three major goals to be achieved by 2027:

- Increasing the competitiveness of agricultural and non-agricultural sectors;
- Sustainable management of natural resources, preservation of ecosystems, and climate change adaptation;
- Ensuring food/feed safety and the development of efficient veterinary and plant protection systems.

The proposed measures lead towards a more sustainable and profitable agriculture sector as they contribute to higher productive livestock, decreased synthetic fertilizer use as well as research and education on the feasibility of sustainable agriculture practices in Georgia.

National Environment and Health Action Plan (NEHAP-2) of Georgia 2018-2022

NEHAP-2 outlines the country's current modalities of establishment and preservation of safe environment, defines priorities of the 5-year period. As highlighted in the NEHAP-2, the main principle is to have a multidisciplinary collaboration towards health in all policies, to prioritise public health in order to realise the right of Georgian population guaranteed by the country constitution – live in a safe environment. The agriculture measures in the CSAP will contribute to reducing the use of fertilisers and therefore improving water quality, which support strategic objective #1 (Improve access to safe water and sanitation) and strategic objective #5 (Integration of health issues in climate change adaptation and mitigation policies).

5.3 Synergies with the Sustainable Development Goals

In 2015, member states of the United Nations adopted the 2030 Agenda, including 17 Sustainable Development Goals (SDGs) and 169 targets. The aim of the 2030 Agenda is to end poverty, protect the planet and ensure that all people live in peace and prosperity. In contrast to the Millennium Development Goals (MDGs), the SDG framework does not differentiate between "developed" and "developing" countries and incorporates additional areas such as climate change, economic inequality, sustainable consumption, innovation, peace and justice. The 17 SDGs of the 2030 Agenda officially came into force in January 2016, applying to all states with no exceptions. SDGs are not legally binding; however, each government is expected to establish an integrated, national SDG strategy with an aim to implement the new sustainable development agenda by 2030.

Agenda 2030 and the SDGs include specific targets relevant to the agriculture sector, such as the implementation of sustainable agricultural practices or the reduction of water pollution. Additionally, there are several other SDG targets, whose fulfilment would be directly or indirectly influenced by the decarbonisation of Georgia's agriculture sector. Figure 12 provides concrete examples of the linkages between climate action in the agriculture sector and the SDGs in the context of Georgia. This shows that the acceleration of planning and implementation of agriculture sector decarbonisation would be of benefit not only from a climate change mitigation perspective, but also would accelerate the implementation of the Agenda 2030 and the SDGs in Georgia.

Target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers. The measures include improved feeding practices for livestock and research on further actions such as improved manure management systems which can enhance agricultural productivity. A successful implementation of cooperatives could further support small-scale farmers.

Target 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, and that progressively improve land and soil quality. The measures include a reduced use of fertilizers, implementation of better irrigation systems and research on the feasibility of climate smart agriculture in Georgia. All of those support the implementation of sustainable and resilient practices.

Target 6.2: By 2030, achieve access to adequate and equitable sanitation and hygiene for all. The measures include a reduced use of fertilizers and the implementation of better irrigation systems leading to a reduction of water contamination.

Target 15.3: By 2030, combat desertification and restore degraded land and soil. The agriculture measures include a reduced use of fertilizers and improved farming practices leading to a possible reduction of land degradation.

Figure 12: Synergies between SDG targets and mitigation actions in Georgia's agriculture sector

A deeper understanding of the synergies between climate action in the agriculture sector and the Agenda 2030 can help unlock further ambition and avoid potential conflicts. In some cases, interactions between the two may be mutually reinforcing, while in other cases action in one may undermine the achievement of the targets in the other. Being aware of potential linkages can support policy makers across different departments and state levels, to achieve greater policy coherence, to enable the achievability of multiple goals and to improve the efficiency of implementation.

6 Coordinating enhanced action

The agriculture sector in Georgia is at a turning point considering the planned introduction of large-scale commercial agriculture. Various projects are in place to help make the Georgian agriculture sector more productive and profitable, which could, on the one hand, lead to increased GHG emissions through increased activity but, on the other, may decrease future emissions through high productive livestock. To ensure that the sector takes a sustainable long-term pathway, Georgia should consider the following steps:

Increase the awareness of the implications of the Paris Agreement for the agriculture sector and the synergies with development objectives among government officials and other sector stakeholders. Efforts to decarbonise the agriculture sector would be fully in-line with and mutually reinforcing other national strategic objectives, including the EU Association Agreement and the Agenda 2030 Sustainable Development Goals (SDGs). Enhanced awareness of these links amongst sector-level stakeholders and national development strategists can assist to identify the most constructive and beneficial options for Georgia as a whole.

Implement an improved agriculture sector data collection, which would increase the accuracy of trajectory projections and the quality of policy formulation. The scenarios in this report are based upon the best available data and knowledge from national experts, but there are considerable uncertainties and knowledge gaps that may compromise the accuracy of activity and emissions projections. Improved data collection: Data collection for agriculture statistics in Georgia should be extended to allow for a more accurate and reliable projection of current and future emissions of the sector, e.g., related to livestock growth or future fertilizer use. This would further make the calculations less dependent on assumptions and outside sources.

Put information exchange and training of farmers at the core of sector action to ensure that planned policies are feasible and aligned with the reality of farmers' situations, and that they have the required resources to implement adopted policies as planned. Cooperation and coordination between government officials, local and international experts, donor organisations as well as small and industrial producers will be needed to design a robust strategy for the sector and ensure effective implementation.

Address land tenure rights in rural areas to create incentives for practices that result in long-term land sustainability and unlock action for many accessible mitigation measures. Several mitigation actions for croplands and livestock, which may be cost-beneficial to farmers and would be ready to implement, are hindered by land tenure uncertainty, which leads to the maximisation of short-term gain over longer-term sustainability.

Review public spending in agriculture to ensure that it efficiently addresses both development and climate objectives. Georgia invests less in agriculture than neighbouring countries, relative to its contribution to GDP. An increase in spending and modernization of the sector – including outside of the main export industries – could boost the economic productivity of the sector while contributing to climate and development targets. Public expenditures on subsidies for fertilisers or fuels might now be counterproductive to the sustainable development of the sector and could be redirected towards training and awareness for sustainable practices.

Prioritise and develop concrete policy feasibility studies and proposals for measures that are within grasp, either for direct implementation or to seek international finance for implementation. For several mitigation measures, technologies and practices are ready and the next steps would be to thoroughly assess different potential policy instruments to roll out those practices. In particular, **manure management** and **fertiliser application management** are practices which are not in widespread use and could be attractive to be prioritised for policy and programme development, given their high mitigation potential and the readiness of technologies and practices. Although climate finance is globally scarce, Georgia has the potential of accessing it with well design implementation plans that include unlocking policy interventions, awareness and capacity building campaigns and appropriate financial mechanisms. Several potential sources of international climate finance are looking for stronger funding proposals, while many of these sources have a high interest in the agriculture sector, partially due to synergies with development objectives. Many of the most relevant finance sources are already active in Georgia.

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Annex I GHG emission trajectory scenario methodologies

Reference emission trajectory

The reference emission trajectory for the agriculture sector – presented in section 2.3.1 – provides an overview of how greenhouse gas emissions from the sector have and are projected to develop in the period from 1990 to 2030.

Definition of reference scenario

The reference emission trajectory considers the estimated development of the sector in the absence of any additional policies and measures that were not already implemented in the base year. It considers a continuation of the current existing policies and sector trends, from that base year.

The base year for the scenario is 2015, the year in which a baseline scenario was first constructed for Georgia's first Nationally Determined Contribution. This analysis provides an update to the original NDC baseline scenario, using a new methodological approach and more up-to-date assumptions.

The scenario includes energy-related greenhouse gas emissions from agriculture sector activity, in a single metric expressed as tonnes of CO_2 equivalent (tCO_2e). The emissions accounted to the sector include emissions from livestock and arable agriculture sectors, including emissions from manure management, enteric fermentation, agricultural soils and energy use in agriculture, fishing and forestry. Agricultural soil emissions include direct emissions from synthetic and organic N fertilizer use, crop residue decomposition and pasture range and paddock as well as indirect emissions from atmospheric deposition and nitrogen leaching and run off. Energy use in off-road vehicles, including those used for agriculture, is not accounted in this sector.

Modelling approach

To estimate emissions from manure management and enteric fermentation, livestock numbers are quantified based on the 2015 values from the Second BUR and by then applying GEOStat growth rates for 2016-2018 for all livestock categories. For projections up to 2030 growth rates from FAO (2020) are applied for cattle livestock and year-specific growth rates from the draft LEDS (2017) for all other animal categories. Emission factors for both enteric fermentation and manure management are taken from Georgia's latest national GHG inventory report (2019) in line with IPCC recommendations.

Emissions from agricultural soils are quantified based on the 2015 values from the Second BUR and by then applying growth rates for each category from FAO (2020) up to 2030. For synthetic fertilizer use updated estimates from GEOStat (2020a) are used for 2016-2018 values.

Fuel combusted in the agriculture sector is based on calibrated 2015 values which grow in line with GDP growth, modelled in a separate exercise using LEAP[2].

A detailed account of sources for both historic and future emissions, as well as assumptions used for projections can be found in Annex II.

[2] The effects of the Climate Strategy and Action Plan measures across all sectors were integrated into a Low Emissions Analysis Platform (LEAP) model along with sector electricity consumption to project the sector's emissions trajectories to 2030. The LEAP analysis involved an economy-wide (all energy sectors) modelling effort.

Climate Strategy and Action Plan emissions trajectory

Definition of Climate Strategy and Action Plan scenario

The Climate Strategy and Action Plan scenario considers the impact of agriculture sector measures proposed for the Plan in Georgia. This scenario uses the reference scenario (including all data indicators, historical data, calculations, and projections) as a base to calculate the additional impact of the suggested measures.

The only action with a direct, quantified impact on emissions reductions for the Climate Strategy and Action Plan 2021-2023 is the improvement of feed quality for up to 20% of cattle livestock, as recommended by sector experts (Winrock and Remmisia, 2017). The fulfilment of the direct action would reduce emissions in the agriculture sector overall by only 0.1% compared to the reference case scenario (6.83 $ktCO_2e$ per year). However, depending on the feasibility of different feeding options in Georgia, the share of cattle, and therefore, the emissions reduction impact could be increased significantly in the future.

Modelling approach

The impact of the agriculture measure was quantified using FAO's Ex-Ante Carbon-balance Tool (EX-ACT) and an Excel-based policy tool developed by the authors, using the following calculation steps:

1. Projections of the number of cattle livestock under the reference case (see Annex II) until 2030 serve as input into the EX-ACT tool.
2. It is assumed that 20% of cattle livestock will receive feed of improved quality by 2021.
3. The reduction rate in emissions from enteric fermentation of cattle livestock is retrieved from EX-ACT and applied to the emissions from enteric fermentation of cattle livestock under the reference case as calculated in the previous chapter.

Figure 13 gives a more detailed overview of the EX-ACT tool.

The EX-ACT tool

EX-ACT is an appraisal system developed by the Food and Agriculture Organization of the United Nations (FAO) providing estimates of the impact of agriculture and forestry development projects, programmes, and policies on the carbon-balance.

The calculations are carried out with the method of so-called 'C Stock Changes' through the changes established as a result of comparing the C stocks for various periods of time. EX-ACT takes into consideration the Guidelines for National Greenhouse Gas Inventories from the IPCC (2006). In line with those IPCC guidelines, the calculations in the forestry sector include five reservoirs of carbon, which are taken into consideration: above-ground biomass, below-ground biomass, litter, deadwood and soil organic carbon.

EX-ACT uses geographic, climate and agro-ecological variables for computations and information related to the changes in the land-utilization and agricultural practices. EX-ACT's computation logic is based on comparing the results of planned measures with the results of a scenario without these measures (reference scenario).

EX-ACT by default uses emission coefficients for first-level computations (according to the IPCC methodology). For the agriculture sector national-level emission coefficients in line with Georgia's National Inventory Report (2019) were entered.

Figure 13: Description of the EX-ACT tool

Annex II Reference scenario data sources and assumptions

<table>
<tr><th colspan="2">Livestock</th></tr>
<tr><td colspan="2">Historical data</td></tr>
<tr><td>Data source(s) used for historical data</td><td>Number of livestock by category:
Georgia's Second Biennial Update Report (2019) and GHGs National Inventory Report of Georgia 1990-2015 (2019)</td></tr>
<tr><td>Last historical year</td><td>2015</td></tr>
<tr><td>Important assumptions</td><td>Livestock categories taken into consideration are late maturing cattle, early maturing cattle, buffaloes, sheep, goats, horses, swine and poultry.</td></tr>
<tr><td colspan="2">Projections</td></tr>
<tr><td>Data source(s) used for projections</td><td>Number of livestock by category:
Cattle (both categories):
2016-2018: Growth rate based on "bovine animal" livestock numbers reported by GeoStat (GEOSTAT, 2020b)
2019 onwards: Growth rates based on average FAOSTAT growth rate based on livestock projections between 2016 and 2030 (FAOSTAT, 2020)
Buffaloes:
2016-2018: Growth rate based on "bovine animal" livestock numbers reported by GeoStat (GEOSTAT, 2020b)
2019 onwards: Growth rates based on projected livestock numbers estimated during development of the draft LEDS – Georgia (Winrock and Remmisia, 2017)
Horses:
No growth assumed since none reported for recent years in both Georgia's Second Biennial Update Report (2019) and by GeoStat (2020b)
Sheep, Goats, Swine and Poultry:
2016-2018: Growth rate based on livestock numbers reported by GeoStat (GEOSTAT, 2020b)
2019 onwards: Growth rates based on projected livestock numbers estimated during development of the LEDS – Georgia (Winrock and Remmisia, 2017)</td></tr>
<tr><td>Last projection year</td><td>2030</td></tr>
<tr><td>Important assumptions</td><td>See above</td></tr>
</table>

Enteric Fermentation	
Historical data	
Data source(s) used for historical data	• Georgia's Second Biennial Update Report (2019) and GHGs National Inventory Report of Georgia 1990-2015 (2019)
Last historical year	2015
Important assumptions	-
Projections	
Data source(s) used for projections?	• **Livestock projections:** see table above • **Emission factors:** GHGs National Inventory Report of Georgia 1990-2015 (2019) based on IPCC methodology
Last projection year	2030
Important assumptions	• To account for the Tier 2 approach for estimating cattle emissions, emission factors from Tier 1 approach for late and early maturing cattle are used to calculate emissions, then the average ratio between Tier 1 and Tier 2 emissions for cattle between 1990-2015 is used to align the emissions projections with the Tier 2 approach

Manure Management	
Historical data	
Data source(s) used for historical data	• Georgia's Second Biennial Update Report (2019) and GHGs National Inventory Report of Georgia 1990-2015 (2019)
Last historical year	2015
Important assumptions	-
Projections	
Data source(s) used for projections?	• **Livestock projections:** see table above • **CH_4 emission factors:** GHGs National Inventory Report of Georgia 1990-2015 (2019) based on IPCC methodology • **N_2O emissions:** Average ratio of N_2O and CH_4 emissions from 2010-2015 based GHGs National Inventory Report of Georgia 1990-2015 (2019)
Last projection year	2030
Important assumptions	• The ratio between CH_4 and N_2O emissions remains constant

Agricultural Soils	
Historical data	
Data source(s) used for historical data	• Georgia's Second Biennial Update Report (2019) and GHGs National Inventory Report of Georgia 1990-2015 (2019)
Last historical year	2015
Important assumptions	Categories taken into account: • Synthetic fertilizers • Organic N fertilizers applied to soils • Crop residue decomposition • Pasture range and paddock (urine & dung) • Indirect soil emissions (*Atmospheric deposition* and *Nitrogen leaching & run off*)
Projections	
Data source(s) used for projections?	Synthetic fertilizers: • Growth rate for 2016-2018 based on GeoStat (2020a) • Growth rate for 2019-2030 assumed to be equal to 2018 Organic N fertilizers applied to soils • Growth rate for 2016-2018 based on FAO Stat (2020) indicator *Direct emissions from manure applied to soils* • Growth rate for 2019-2030 based on 2030 projection Crop residue decomposition • Growth rate for 2016-2018 based on FAO Stat (2020) indicator *Direct emissions from crop residues* • Growth rate for 2019-2030 based on 2030 projection Pasture range and paddock (urine & dung) • Growth rate for 2016-2018 based on FAO Stat (2020) indicator *Direct emissions from manure left on pasture* • Growth rate for 2019-2030 based on 2030 projection Indirect soil emissions • Growth rate for 2016-2018 based on FAO Stat (2020) indicators *Indirect emissions from synthetic fertilizers, manure applied to soils, manure left on pasture & crop residues* • Growth rate for 2019-2030 based on 2030 projection
Last projection year	2030
Important assumptions	Growth rates for each category remain constant between 2018-2030

Annex III Reference and CSAP scenario data

Scenario	Indicator	Coverage	Unit	1990	1995	2000	2005	2010	2015	2020	2025	2030
Reference Case	Emission enteric fermentation	All GHGs	kt CO2e	1,619.31	1,127.28	1,321.53	1,357.86	1,184.82	1,472.31	1,373.63	1,537.51	1,722.80
Reference Case	Emissions manure management	All GHGs	kt CO2e	564.52	370.18	435.05	443.98	359.84	449.72	433.62	536.42	660.15
Reference Case	Emissions agricultural soils	All GHGs	kt CO2e	1,742.20	1,058.13	1,264.80	1,329.90	1,168.70	1,351.60	1,354.13	1,699.70	2,156.90
Reference Case	Total Emissions	All GHGs	kt CO2e	**3,926.03**	**2,555.59**	**3,021.38**	**3,131.74**	**2,713.36**	**3,273.63**	**3,161.39**	**3,773.64**	**4,539.86**
Reference Case	Emissions from enteric fermentation	Methane	Gg CH4	77.11	53.68	62.93	64.66	56.42	70.11	65.41	73.21	82.04
Reference Case	Emissions from manure management	Methane	Gg CH4	9.02	5.38	6.25	6.38	4.44	5.62	5.44	6.73	8.28
Reference Case	Emissions from manure management	Nitrous oxide	Gg N2O	1.21	0.83	0.98	1.00	0.86	1.07	1.03	1.27	1.57
Reference Case	Emissions from agricultural soils	Nitrous oxide	Gg N2O	5.62	3.41	4.08	4.29	3.77	4.36	4.37	5.48	6.96
CSAP scenario	Total Emissions	All GHGs	kt CO2e	**3,926.03**	**2,555.59**	**3,021.38**	**3,131.74**	**2,713.36**	**3,273.63**	**3,161.39**	**3,766.81**	**4,533.03**
Both	Energy-use	All GHGs	kt CO2e	**524.00**	**419.50**	**182.00**	**280.00**	**307.00**	**38.00**	**48.76**	**64.64**	**84.08**

Source: *Historical data points come from official sources, such as national inventories and Biennial Update Reports submitted to UNFCCC. All other data points, including projections, come from authors calculations modelled in Excel and using the EX-ACT tool. Energy-use for "agriculture, fishing and forestry" has been modelled in a separate exercise in LEAP*

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