Evaluation of manure management alternatives in Georgia

An analysis to identify best manure management options in Georgia

Authors:
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On behalf of:
Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
of the Federal Republic of Germany

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Cover picture: Ilia Kunchulia

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List of Acronyms

ASF	African Swine Fever
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CSAP	Georgia’s 2030 Climate Change Strategy and 2021-2023 Action Plan
DCFTA	Deep and Comprehensive Free Trade Area – Georgia
EBRD	European Bank for Reconstruction and Development
EU	European Union
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEOSTAT	Georgia’s National Statistics Office
GHG	Greenhouse Gas
MEPA	Georgia’s Ministry of Environment Protection and Agriculture
NDC	Nationally Determined Contribution
NEAP	National Environmental Action Programme
PM	Particular Matter
RDA	Georgia’s Rural Development Agency
USAID	United Stated Agency for International Development

1. Introduction and objectives

Georgia's 2030 Climate Change Strategy and 2021-2023 Action Plan (CSAP) represents a coordinated effort and planning towards meeting the target set in the country's updated nationally determined contribution (NDC) for climate change mitigation. It includes specific planned actions in seven sectors of the economy. For the agriculture sector, one of the objectives listed in the CSAP is to build capacities and to generate scientific evidence for the development of climate-smart approaches. This is aligned with other national policies like the National Strategy on Agricultural Extension in Georgia and the Rural and Agricultural Development Strategy of Georgia. Developing climate-smart approaches includes, among others, the identification of the most suitable measures for practicing manure management, which are likely to be planned and implemented under the next Climate Action Plan beyond 2023.

In this context, this study was commissioned to develop an in-depth analysis that explores different options in which manure management systems can be implemented in the Georgia-specific context. The study also considers their feasibility in light of national circumstances.

The report includes the following sections:

Section 2 describes the current situation of the agriculture sector in Georgia, including a description of how the sector is set up, main activities and projections of its development in the future.

Section 3 gives a brief overview of the relevant current policies related to manure management practices, including climate-related, agricultural development and waste management policies and regulations.

Section 4 presents the current and future emissions for the sector, based on the reported emissions inventories and taking into account the impacts of the projected agriculture and livestock growth.

Section 5 describes different manure management options available globally, while **Section 6** presents an **assessment of three prioritised measures** that could be considered for implementation in the Georgian context.

A short conclusion and high-level recommendations are provided in Section 7, closing this report.

2. The agriculture sector in Georgia

This section of the report describes the current situation of the entire agriculture sector in Georgia, starting with a description of how the entire sector is set up, and the main activities and projections of its development in the future.

2.1. Background and context

In 2020, the agriculture sector employed around 19% of the Georgian population (GEOSTAT, 2022). Of this workforce, most of them are categorized as “self-employed” or small-scale subsistence farmers. Also, most livestock are held in small-scale family holdings, including more than 97% of bovine animals, 80% of swine and about 40% of poultry (GEOSTAT, 2021a). The sector’s contribution to national GDP has been declining, from 25% in 1999 to 8.4% in 2020 (GEOSTAT, 2021d).

Low labour productivity (reflected in their monthly incomes) is the main reason of poverty for people employed in the agriculture sector in Georgia and has continuously been affecting the competitiveness of Georgian agricultural products in the domestic and global markets (Transparency International Georgia, 2020). In 2020, the share of income derived from the sales of agricultural production constituted only 5.3% of total household income. About 60% of agricultural holdings produced primarily for own consumption, while less than 5% of all agricultural holdings producing primarily for sale (GEOSTAT, 2021b).

In Georgia, 43% of the total land area is categorised as 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, 2021). Between 2013 and 2019, GEL 1.5 billion (EUR 452 million) from the state budget of Georgia was spent on agricultural development and the ‘Government Program 2021-2024’ foresees another GEL 1 billion (EUR 301 million) in financial resources for the development of the agricultural industry over that timeframe (Government of Georgia, 2020; Transparency International Georgia, 2020).

Considering the expected rise in production levels, mainly due to the expected development of large-scale commercial agriculture, it is necessary to embed sustainable business practices from the beginning onwards to ensure a sustainable long-term pathway for the sector. 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 contribute to decreasing future emissions through higher productivity, efficiency and the more sustainable use of resources.

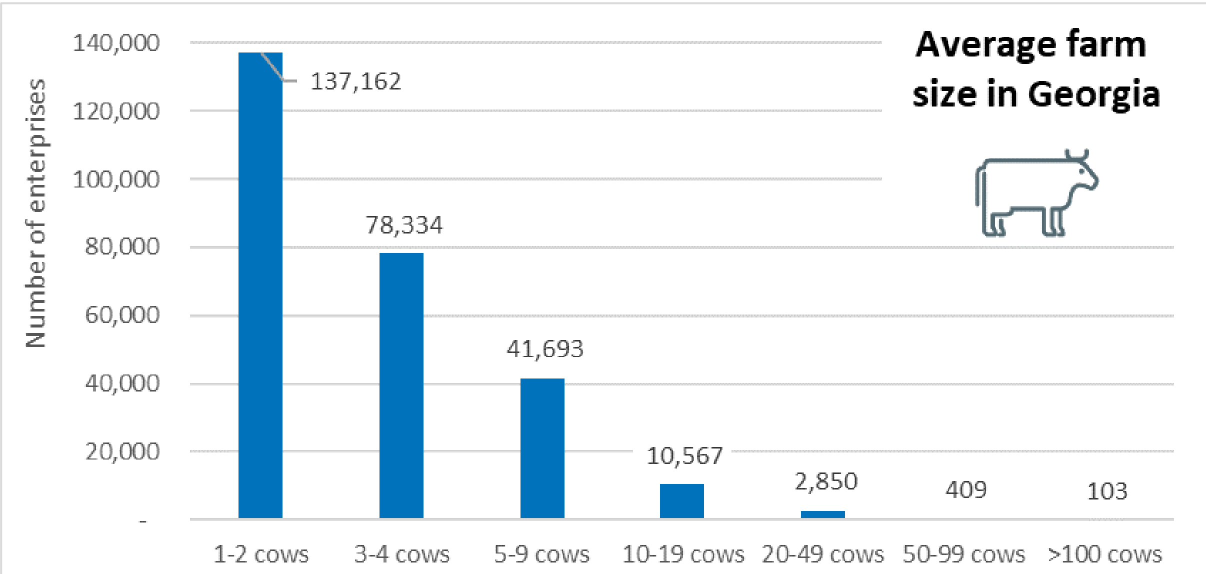
Agricultural development is already one of the priority areas of the Georgian Government as outlined in the ‘Government Program 2021-2024’ and the ‘Agriculture and Rural Development Strategy of Georgia 2021-2027’. The strategy particularly considers the implementation of climate smart agriculture practices although there are currently few specific concrete plans for the achievement of that objective and no mention of specific measures to achieve it (e.g., through better manure management practices).

2.2. Georgia's livestock sector

As of 2020, the agricultural output of Georgia increased to about GEL 5.5 billion (EUR 1.7 billion) from GEL 3 billion (EUR 904 million) in 2018, 48% of which comes from animal husbandry, 45% from plant growing and 7% from agricultural services (GEOSTAT, 2021b). In 2021, agri-food exports amounted to EUR 1.1 billion. This represented a record-high year and 124% higher than in 2012. Fresh fruit exports accounted for almost 19% of the value, fresh vegetables for 2.5% and live cattle alone represented 3% of agri-food exports (MEPA, 2022).

Cattle is the predominant type of livestock husbandry, although with the vast majority of farmers in all regions owning less than ten heads of cattle on average. Figure 1 shows the average farm size in terms of number of heads of cattle; only 0.04% of the enterprises have over 100 cows, while 95% have less than ten cows in their farms. A similar trend is observed for sheep, goats and swine which are almost exclusively held on small family farms (GEOSTAT, 2021b; UNECE, 2018).

Figure 1. Farm size in Georgia per number of cows

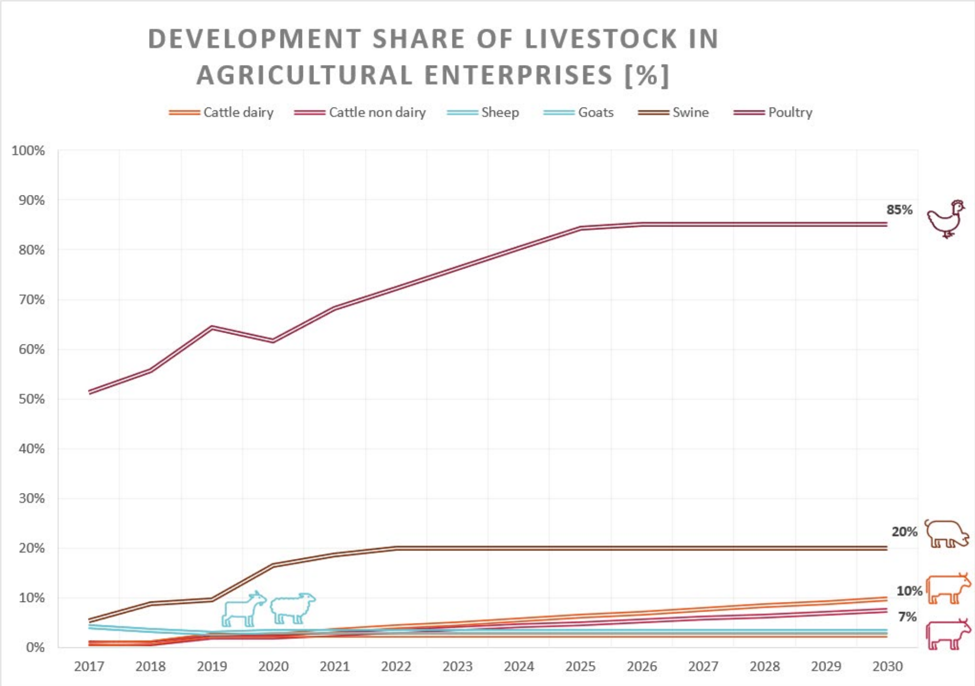


Source: Graph based on data from GEOSTAT (2014)

In recent years however, the share of livestock in agricultural enterprises has been slowly growing. In 2020, agricultural enterprises held 2.5% of dairy cattle, 2% of non-dairy cattle,17% of swine and more than 60% of poultry livestock (GEOSTAT, 2021b) .

Based on the trend observed between 2017 and 2020, we project that by 2030 roughly 10% of dairy cattle, 8% of non-dairy cattle and 85% of poultry livestock will be held in agricultural enterprises compared to small-scale farms (Figure 2). Although the trend for pigs moving from family holdings into enterprises seemed to be increasing over the last years, going from 5% to 16% between 2017 and 2020, we assumed this share would not go beyond 20% in the future due to the risk of them contracting the African Swine Fever (ASF) virus. The ASF virus was first reported in the country in 2007, when more than 30,000 pigs died and almost 4,000 pigs were culled. The country has not been able to recover until now and farmers do not want to increase the number of pigs in their farms to avoid risk of losses (FAO, 2008) .

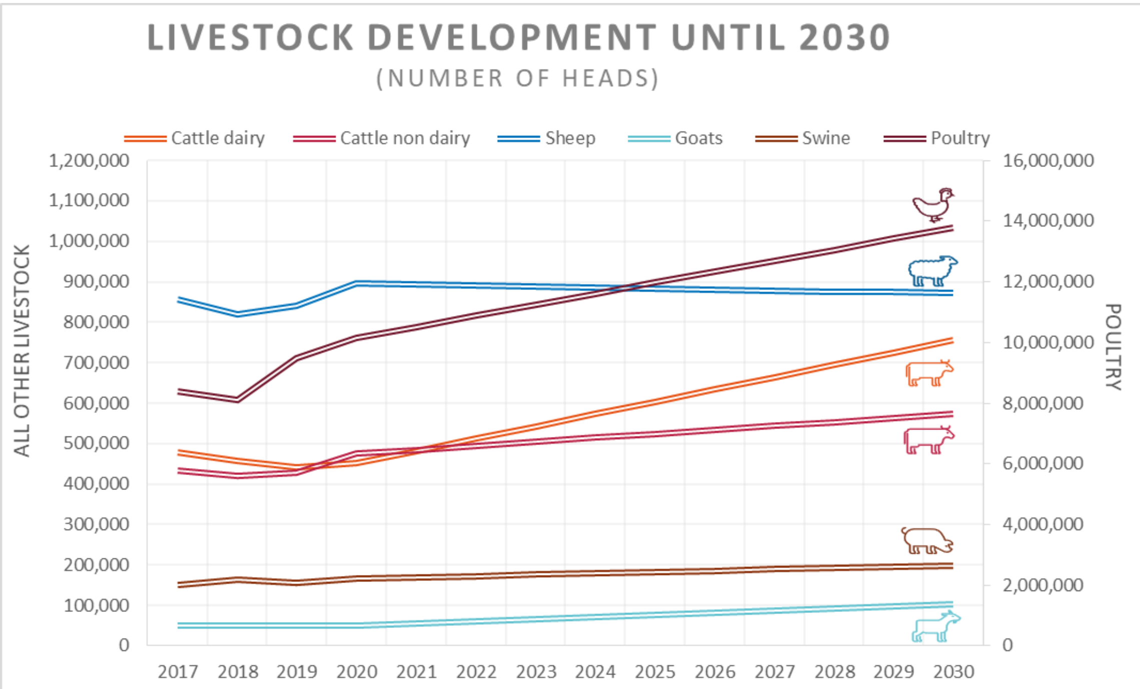
Figure 2. Projected share of livestock in agricultural enterprises 2017-2030



Source: Own projections based on historical trend from GEOSTAT (2021a); share of swine was capped at 20% to reflect developments after the African Swine Fever (ASF) virus.

Figure 3 represents the development of livestock in Georgia until 2030 by type of livestock. Until 2020 the numbers are based upon the most recent available data from Georgia's Agricultural Yearbook 2021. For the projections thereafter we apply growth rates calculated based on the FAO livestock projections for Georgia (FAOSTAT, 2021).

Figure 3. Livestock projections until 2030



Source: Own projections based on historical trend from GEOSTAT (2021a); swine population was capped at 200,000 to reflect developments after the African Swine Fever (ASF) virus.

Several projects implemented by the Rural Development Agency (RDA) and funded by the Georgian state budget subsidise and aim to support the development of the Georgian agriculture sector. The Preferential Agrocredit Project can be considered as one of the most relevant incentives for the development of large-scale livestock farms (ProCredit Bank of Georgia, 2021). The project supports the building of farm and processing infrastructure as well as machinery for up to GEL 15 million (EUR 4.5 million). However, financial resources are only provided for fixed assets and infrastructure, not the purchase of livestock. Other projects funded by the state budget are focusing on the development of cooperatives or agricultural mechanisation (MEPA, 2021d).

Additionally, there are projects issuing co-financing grants and loans from USAID, EU, EBRD, and others. Since 2019, the Georgian Farmers' Association is implementing the Safety and Quality Investment in Livestock (SQIL) project which runs for five years and is funded by USAID to improve competitiveness of the Georgia dairy and beef industries (Georgian Farmers' Association, 2021). Another project by the Georgian Farmers' Association with financial support from the International Fund for Agricultural Development (IFAD) is the Dairy Modernisation and Market Access (DiMMA) Programme. This runs from 2021-2023 and aims to establish a diversified and sustainable dairy sector through the improvement of infrastructure, trainings and implementation of new standards and international best practices for small-scale dairy production (IFAD, 2021).

Similarly, the European Neighbourhood Programme for Agriculture and Rural Development (ENPARD) aims to boost Georgia's potential in agriculture and rural development by improving the livelihoods of rural communities and creating employment opportunities (UNDP, 2021). ENPARD is running from 2013 until 2025 and is funded by the European Union and implemented by UNDP in cooperation with the Georgian Government and a wide range of international and national partners and stakeholders.

3. Relevant policies and targets

This section gives a brief overview of the current policies that are relevant in the context of manure management practices, including climate-related, agricultural development and waste management policies and regulations.

3.1. National Policies and Targets on Agriculture and Climate Change

Nationally Determined Contribution (NDC)

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). Under the baseline scenario, that is, without any further measures to reduce emissions, economy-wide emissions (excluding land-use, land-use change and forestry) are projected to increase on average 4% per year between 2020 and 2030. In this scenario, 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 in the agriculture sector but states the intention to "support the low carbon development of the agriculture sector" (Government of Georgia, 2021).

2030 National Climate Strategy and 2021-2023 Action Plan (CSAP)

The CSAP emissions' 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 mitigation actions are fully implemented. Under this scenario, agriculture sector emissions continue to increase from 3.31 MtCO_2e in 2015 (direct emissions only) to 4.617 MtCO_2e in 2030 (+40% compared to 2015 levels), even after implementing the identified mitigation actions (MEPA, 2021a). These emission levels represent less than 1% reduction or 7 ktCO_2e in 2030, compared to the reference scenario. For the agriculture sector the CSAP measures include the implementation of sustainable management practices for soil and pastures, improved feeding practices and generating scientific evidence for the development of climate-smart agriculture approaches throughout the sector.

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 a 5-year period. The NEAP-3 includes a chapter dedicated to climate change, which includes actions to create enabling conditions for GHG emissions reductions, including the action to develop a Climate Action Plan, an updated NDC and a Long-Term Low-Emission Development Strategy (LT LEDS). The NEAP-3 also includes specific targets for the reduction of water pollution and air pollution, the implementation of which can be supported by several of the measures of the Climate Strategy and Action Plan.

3.2. National Programs and Strategies on Agricultural Development

Rural and Agricultural Development Strategy of Georgia – 2021-2027

The strategy outlines three major goals to be achieved by 2027, contributing to higher productive livestock, decreased use of synthetic fertiliser and promoting research and education for sustainable agriculture practices in Georgia (MEPA, 2019). With regard to climate change, the strategy focuses mostly on responding to the risks of climate change through adaptation, though some of the measures in the strategy would have relevance for climate change mitigation targets. For example, disseminate climate-smart practices, promoting sustainable use of forest resources and improving energy-efficient and renewable energy use under Goal 2, to make sustainable usage of natural resources, retaining the eco-system, and adapting to climate change.

Government Program 2021-2024

The Government Program 2021-2024, adopted in December 2020, outlines the key goals of the Government's agricultural policy, which is to increase agricultural product exports and to reduce import dependence. Additional goals of the program include enhancing the competitiveness of agricultural products, providing stable production growth and food safety, as well as the overall development of rural areas, including addressing problems inflicted by the impacts of the COVID-19 pandemic. To develop the national agricultural industry the Government wants to spend more than GEL 1 billion (EUR 301 million) of the state budget.

National Strategy on Agricultural Extension in Georgia 2022-2027

The purpose of the extension strategy is to provide farmers with the knowledge and information they need to farm better. The goal of the strategy is to enhance the competitiveness of farmers and rural entrepreneurs and support climate-smart agricultural production in Georgia in a sustainable and environmentally friendly manner. It will further support investments into food safety and access to all markets making use of good agricultural practices, using the newest and/or most appropriate innovations. This strategy is currently under development and not yet published.

3.3. National Legal Framework for Manure Management

There are several laws, technical regulations and ordinance of the Government of Georgia[1] which are broadly covering manure management; however, they remain very general and do not go into any specific detail. These laws can be divided into the following sub-categories:

- Waste management plans where manure is identified as a waste product although it is often just mentioned as a type of waste with no indication on how to manage it

[1] Some examples include the Waste Management Code of the Law of Georgia (2015); Resolution №198 of the Government of Georgia on organic production (2014); Order №2-113 from the Minister of Agriculture of Georgia on Approval of the List of Substances Permitted in the Production of Organic Products (2008); Resolution №435 of the Government of Georgia on instrumental method for determining the actual amount of emissions from stationary sources of pollution into the ambient air (2014); and, in particular, the Resolution No. 605 of the Government of Georgia on health rules of non-food products of animal origin (including waste of animal origin) and by-products, which are not intended for human consumption, and rules for recognition of business operators working with the same (2018).

- Animal export/import/transit rules and slaughterhouse waste management
- Prevention and management of animal diseases, sanitary and phytosanitary rules, animal quarantine rules
- Animal feed and fodder hygiene rules, including for pastures
- Soil, water and environmental protection rules indicating manure as a potential pollutant, e.g., prohibiting discharge into water bodies
- Rules about bioproduction and materials allowed in biological and organic farming
- DCFTA agreement, business operator recognition and control measures (regulated by the National Food Agency)

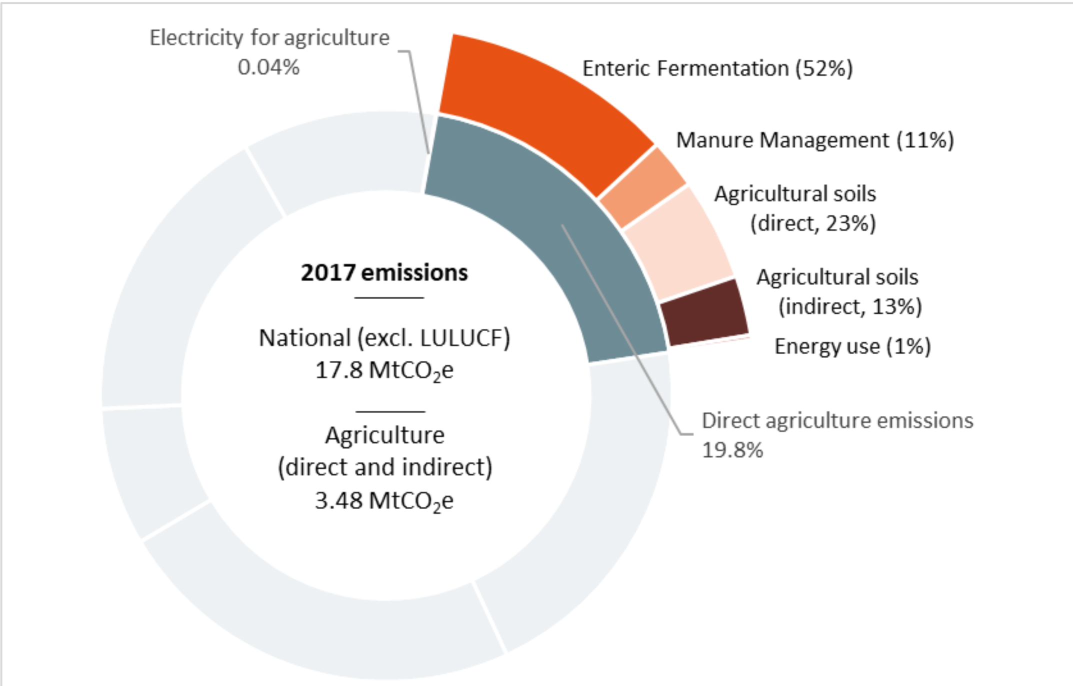
4. Agriculture and manure management emissions

This section of the report presents the current level as well as the future emissions projection for the sector, based on the reported emissions inventories and taking into account the impacts of the projected agriculture and livestock growth.

4.1. Current emissions levels

Georgia's Sixth National Greenhouse Gas Inventory, published in 2021, reports national and sectoral emissions levels up to the year 2017. As shown in Figure 4, the agriculture sector accounted for approximately 20% of GHG emissions (3,532 $GgCO_2e$) in 2017. That year, emissions from enteric fermentation accounted for the majority of the sector's GHG emissions (52%), followed by emissions from agricultural soils and manure management, accounting for 36% and 11% of emissions, respectively (MEPA, 2021). Energy-related emissions represented just about 1% of the sector emissions. This is in line with regional trends, where literature reports that for the Eastern Europe and West-Central Asia region, the main drivers of agriculture emissions are enteric fermentation (46%), manure management (11%), and synthetic fertilisers (10%) (Roe et al., 2021).

Figure 4. Agriculture sector GHG emissions breakdown for 2017



Source: Own elaboration based on data from MEPA (2021b and 2021c).

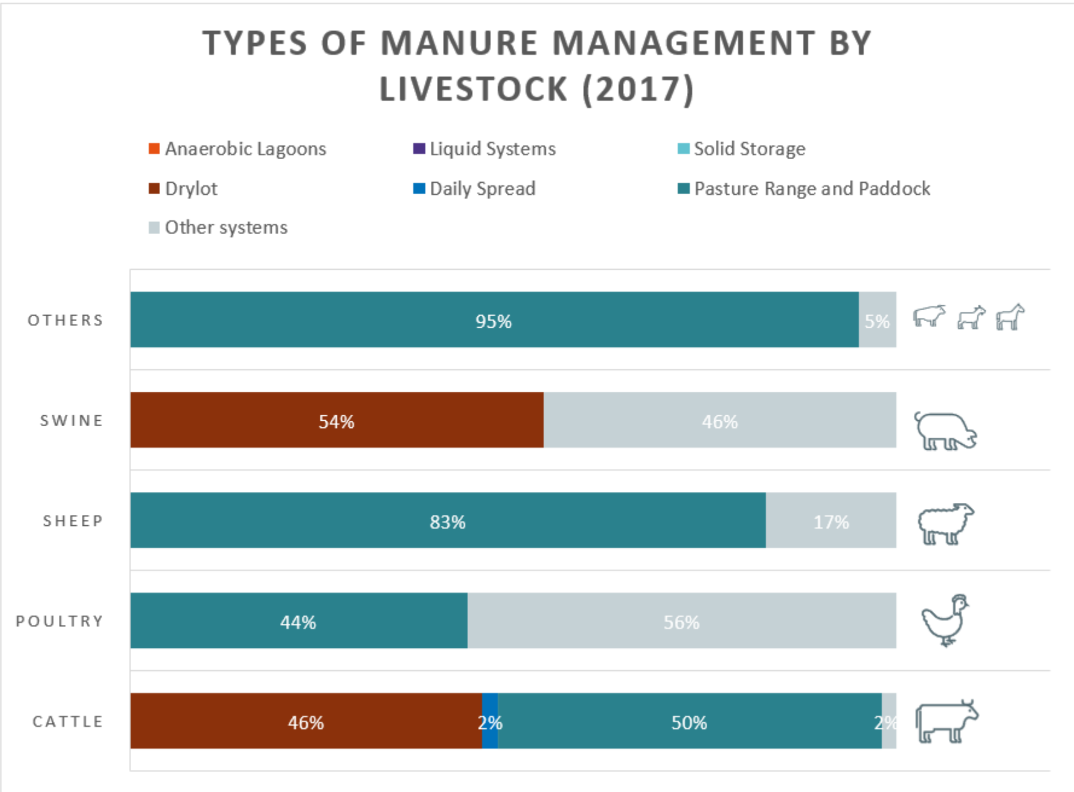
Manure emissions are linked to the high concentration of nitrogen and organic matter in urine and faeces excreted in animal housing, during storage and further treatment, and afterwards during its application to agricultural soil (Mohankumar et al., 2018). Nitrogen is mostly released to the atmosphere in the form of ammonia (NH_3) that can later transform into indirect emissions of nitrous oxide (N_2O). The organic matter in manure produces methane (CH_4) emissions when it is anaerobically decomposed, which occurs when manure is managed in liquid form, for example in lagoons or holding tanks (Gerber et al., 2013).

Emissions from manure application to crop fields as fertiliser can vary significantly depending on the temperature and humidity at the time of application, so good practices for manure application can lead to important emissions reductions (Gerber et al., 2013). Another important share of manure emissions comes from ‘unmanaged’ manure, also known as *manure left on pasture*. This is the case especially in countries where grazing systems are the dominant practice, such as Georgia.

Managing this manure is quite challenging and generally unlikely given how disperse manure is in the fields. However, in summer pastures leased to farmers by the government, most of the manure actually accumulates in the fenced shelters where animals spend the night. This represents an opportunity to introduce management practices, especially because as being state-owned, the government can create standards and incentives to ensure farmers manage manure and other wastes properly. Looking at the livestock systems in Georgia (Figure 5), we see that about 50% of cattle is currently on pasture range and paddock systems; 44% in the case of poultry, 83% for sheep and 54% of swine. This highlights the significant role that pasture range and paddock systems currently have in the national context and is also aligned with the fact that emissions from *manure left on pasture* have an important contribution to the sector’s emissions (MEPA, 2021c).

The other dominant practice for cattle and swine is drylot systems. Drylot systems are similar to feedlots in the sense that cattle is kept in open corrals with bedding areas under covered sheds. The corrals include concrete feeding aprons along the perimeter of the corrals (BioCycle, 2012). In terms of manure management, solid wastes are typically scraped from the concrete feed apron on a daily basis (daily scrape) and from the corral weekly (weekly scrape). The collected manure is typically spread and dried to be later use in the fields as fertiliser (BioCycle, 2012). These systems represent 46% and 54% of manure nitrous oxide emissions of cattle and swine, respectively (MEPA, 2021c).

Figure 5. Types of manure management in Georgia, by type of livestock.



Source: Own elaboration based on data from MEPA (2021c)

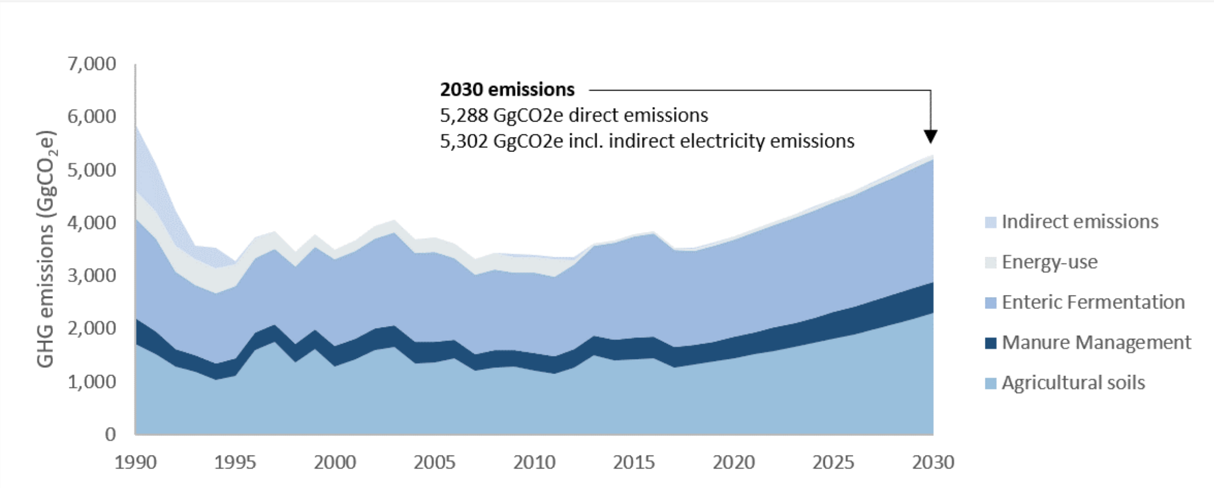
Although manure management accounts for *only* 11% of agriculture emissions in Georgia, it offers key opportunities for mitigation actions that also bring economic, social and environmental co-benefits (Teenstra et al., 2014). Manure contains nutrients and organic matter, and its correct management can help improve soil health and fertility when used as organic fertiliser. Furthermore, the amount of organic fertiliser used per hectare has been fluctuating significantly since 2013, suggesting there is room for improvement in the application practices (GEOSTAT, 2021). Manure can also act as a source of energy for small and large-scale farms while improving access to fuel and public health by reducing black carbon emissions from burning firewood (Teenstra et al., 2014).

4.2. Future emissions projections

Under the reference scenario[2], emissions from the agriculture sector are projected to increase by approximately 50% to 5,288 GgCO_2e in 2030, compared to 2017 levels (Figure 6). Emissions from agricultural soils are expected to grow by 70% between 2017-2030 and account for the majority of the overall projected growth in sector emissions.

The anticipated industrialisation of livestock farming is a major driver in the growth of emissions from the livestock sector. Enteric fermentation emissions are projected to increase by 26% between 2017 and 2030, while emissions from manure management increase by 52%. Cattle was the source of 92% of emissions from enteric fermentation and 82% of emissions from manure management in 2017 and would remain the major source of these emissions up to 2030.

Figure 6. Reference scenario emission trajectory for agriculture (1990-2030)



Source: Own elaboration based on methodology and data from MEPA (2021c and 2021a)

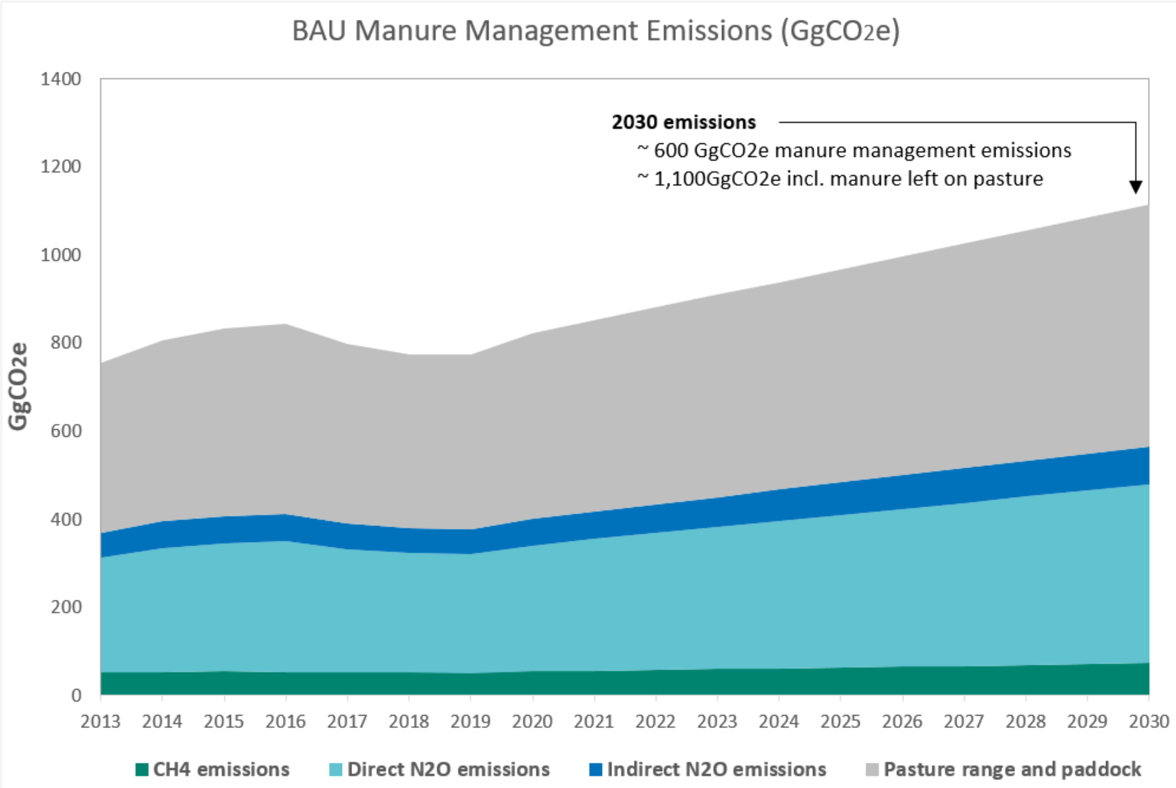
For a deep dive into manure management options for Georgia, we took a closer look at manure-related emissions overall, which can be roughly divided into emissions from manure left on pasture (*unmanaged*) and emissions from manure management. The projections are based upon the latest available emissions data from Georgia's Sixth National Inventory Report and the projection of livestock numbers as outlined in section 2.2 (MEPA, 2021c).

According to our projections, under a baseline scenario, manure left on pasture will continue to be a significant source of manure-related emissions (48%) for Georgia in 2030 (Figure 7). Manure

[2] The reference scenario for the agriculture sector provides an overview of how GHG emissions are expected to develop until 2030. The methodology follows the one used for the Climate Strategy and Action Plan (CSAP) in combination with the latest available emissions data from Georgia's Sixth National Inventory Report (MEPA, 2021c, 2021a) .

management emissions on the other hand, are further subdivided into methane emissions, and direct and indirect nitrous oxide emissions. As shown in Figure 7, the largest share of manure management emissions comes from direct nitrous oxide emissions.

Figure 7. Manure related emissions development under baseline scenario (1990 – 2030)



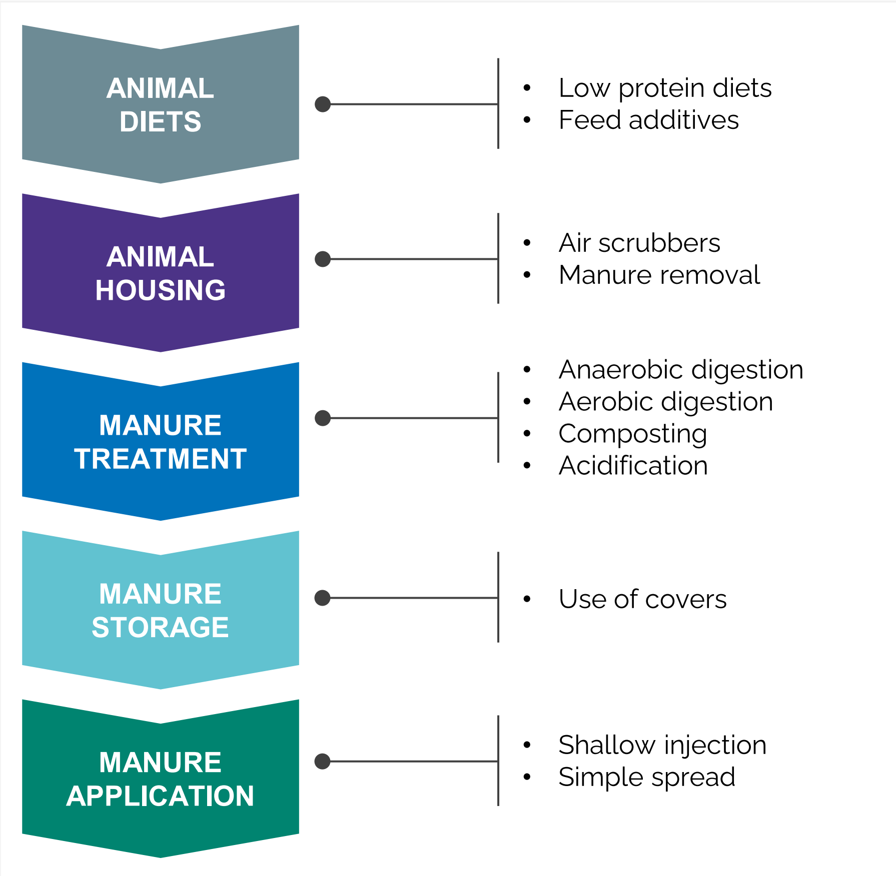
Source: Own elaboration for this report

5. Types of manure management

Manure management practices have many variations, reflecting the diversity of livestock systems, their size, their intensity and productivity. These practices can be implemented throughout the management chain, going from animal feeding to the application of manure to soils as fertiliser. We subdivided the manure management chain into five steps: animal diets; animal housing; manure treatment; manure storage and lastly, manure application; broadly following the approach from Mohankumar et al. (2018). Each step of the chain is associated with different levels of emissions; similarly, emissions from each step can be influenced by different management practices as shown in Figure 8.

Mitigation measures related to manure left on pastures are not directly analysed in this report because of the small likelihood of its management given how disperse manure is in the fields; even in cases where the manure can be collected for fuel or fertiliser use, it often occurs after it is dry and CH_4 emissions are negligible (Herrero et al., 2016). Measures addressing animal diets, however, can improve nitrogen utilization and reduce nitrogen excretion rates, indirectly contributing to reduced emissions from manure left on grazing fields (Mohankumar et al., 2018)

Figure 8. Manure management practices in each step of the chain



Source: Own elaboration based on Mohankumar et al. (2018)

Animal diets

Altering animal diets can change methane, nitrous oxide and ammonia emissions levels (Einstein-Curtis, 2018; Nampoothiri et al., 2015; Seradj et al., 2018; Tieri, 2021). In particular, the protein and fibre content levels of the animal diets are considered major determining factors for GHG emissions of cattle and pigs' manure, when using intensive production systems. For example, in pig farms, about 20% of dietary nitrogen is absorbed by the animal while about 50% of it is lost as ammonia. Ammonia volatilization and subsequent atmospheric deposition is a source of indirect N_2O emissions (Mohankumar et al., 2018). Further, in the case of cattle, improving animal diets can also contribute to reducing methane emissions from enteric fermentation.

Animal housing

The installation of chemical or biological **air scrubbers** helps remove pollutants from air being exhausted from mechanically ventilated buildings. They can reduce dust or particulate matter (PM), ammonia (NH_3) and odour emissions from pig and poultry housing facilities (Mohankumar et al., 2018). Chemical scrubbers are generally more effective in reducing NH_3 emissions than biological scrubbers. However, air scrubbers have limited potential to remove greenhouse gases like methane (CH_4) and nitrous oxide (N_2O); in fact, some studies indicate that biological air scrubbers might actually lead to an increase in N_2O emissions (Melse & Mosquera, 2014; Mohankumar et al., 2018; Van der Heyden et al., 2015).

Another alternative to manage emissions in animal housing is to **increase the frequency of manure removal**, since emissions are dependent on the total amount of manure accumulated. Switching to daily or weekly removal of manure reduces ammonia emissions, as well as CH_4 and N_2O emissions. This approach highly depends on where manure is taken to after being removed from the livestock housing (see manure storage section below). In general, outside storage of manure, under lower temperatures, is likely to further reduce the amount of CH_4 emissions released compared with manure stored indoors (Amon et al., 2007).

Manure treatment

Manure treatment refers to techniques by which manure can be handled to ensure lower emissions and, in some cases, generate energy. There are a few manure management techniques that are well-known and currently being implemented in many countries.

Anaerobic digestion is a mature technology for manure management that is in widespread use worldwide. In the anaerobic digestion, the collected liquid manure from the corrals is treated by specific bacteria in absence of oxygen to produce methane (P. P. Reddy, 2015). The methane is then collected and either flared or used to generate electricity, resulting in carbon dioxide emissions instead of methane emissions. This reduces the emissions impact because methane is a powerful greenhouse gas —about 21 times more powerful than carbon dioxide at warming the Earth. In addition, the anaerobic digestion process creates potentially valuable by-products, such as the solid and liquid fraction of the treated manure, each with available nutrients and potential applications.

Aerobic digestion refers to a biological manure treatment processes that occurs in the presence of oxygen and leads to a reduction in odour, ammonia emissions, chemical oxygen demand (COD), biochemical oxygen demand (BOD), and pathogen control (CTCN, n.d.; LPELC, 2019). However, it is not widely used in treatment of liquid or slurry manure primarily due to the costs associated with operating the motors, compressors or fans required to supply enough oxygen to support aerobic bacteria. This type of management requires generally higher capital costs (i.e. for aeration equipment), higher operating maintenance costs and is very energy-intensive (LPELC, 2019).

Composting is a very common manure management technic, applied worldwide. When the liquid manure is separated from the solids, slurries can be composted by mixing the solids with a carbon source such as straw, peat or wood shavings (CTCN, n.d.). If liquids and solids are not previously separated, composting is still possible but it requires a larger amount of materials (carbon sources) to retain the liquid (CTCN, n.d.).

Acidification of manure refers to the addition of acids to the manure slurry ponds to reduce emissions (Mohankumar et al., 2018). This practice is considered to have one of the highest emissions reduction potentials for both methane and ammonia, as reported in studies from Denmark where this approach is widely being used to control ammonia. Its implementation in other parts of the world, however, is rather limited due to concerns over the safe handling of the acids and uncertainty regarding the long-term impacts on soils (UNEP, 2021)

Manure storage

Manure needs to be stored after removing it from animal houses or after it's been treated, mainly to allow for appropriate timing for its application to soils and to relieve land around livestock housing (which is often constrained). When not stored appropriately, manure starts to degrade, leading to emissions, odours, loss of fertiliser value, etc.

The use of **covers** can help manage these emissions, using chopped straw, wooden lids, granules, floating films, plastic covers, roofs, or others (Bittman et al., 2014; Mohankumar et al., 2018). Studies show that the use of covers can significantly reduce ammonia emissions as the extent of NH_3 produced depends on the surface area of exposed manure. Similarly, methane emissions from stored manure are reduced with the use of covers, although studies suggest some variations depending on the type covering material selected (straw, formation of surface crusts, etc.) and the storage conditions (time, weather, etc.). Importantly, the use of covers may lead to an increase in N_2O emissions, again, depending on the covering materials used. While covering materials such as formation of surface crust, addition of straw, and the use of granules lead to higher N_2O emissions; other materials like wooden lids or plastic films could reduce N_2O emissions through the elimination of oxygen (Mohankumar et al., 2018). Further research is still needed globally to better understand the N_2O emissions effect with the use of different cover materials.

Manure application

The application of animal manure to the field contributes to increase in soil organic matter and soil quality, while reducing ammonia and nitrous oxide if good timing and form of application are taken into account; for example, if manures are applied to match plant nitrogen demand, and at times that avoid heavy rains (Herrero et al., 2016; Mohankumar et al., 2018).

6. Evaluation of prioritised mitigation options

To prioritise manure management options in the Georgian context, we look into the options described in section 5 of this report, combined with the characteristics of the sector and its expected development in the country, as described in sections 2 and 4. Through this overview, combined with consultations with local experts in the topic, a number of measures were deemed not suitable for the Georgian context in the short term, while others seemed more realistic and likely to be implemented. The later included **manure composting**, the **use of covers** when storing it and manure **application as a fertiliser**. These three practices were then prioritised for a more in-depth evaluation of potential and feasibility for climate action in the short term.

Table 1 shows a summary of all other manure management practices considered but not prioritised and the arguments why these measures are not further evaluated. In general, the small scale of Georgian farming is a recurring issue when analysing widespread technology deployment or practices that require significant initial investments. Similarly, a few of the manure management practices are most efficient in intensive systems where animals are kept in feedlots and where their conditions can be altered in a controlled way. In Georgia, large-scale intensive systems are not common, and the average farm is rather small in size or having cattle grazing on pastures rather than being fed in feedlots.

Further, looking at the emissions profile as presented in the latest National GHG Inventory Report (MEPA, 2021c), we find that the mitigation potential of manure management is most relevant when looking at options addressing cattle. In 2017, cattle contributed to 60% and 75% of methane and nitrous oxide emissions from manure management, respectively. Swine is another important source of methane emissions from manure (about 25%), but since the first cases of African Swine Fever in Georgia in 2007, only small-scale farmers raise pigs, and the herd size is kept rather small, limiting the impact of any new proposed manure management practices. We therefore focus the assessment of the prioritised measures on cattle farms only.

Table 1. List of manure management practices assessed but deprioritised for further evaluation

Category	Practice	Arguments
Animal diets	Altering animal diets	» Most relevant for large-scale, intensive farms with animals kept in feedlots. » Feed that can impact methane production through enteric fermentation can be more expensive that regular feed.
Animal housing	Air scrubbers (chemical or biological)	» Scrubbers can reduce dust or particulate matter (PM), ammonia (NH_3) and odour emissions, but have limited potential to remove greenhouse gases like methane (CH_4) and nitrous oxide (N_2O). » Most commonly practiced in pig and poultry housing facilities, which were not identified as primary emissions contributors. » Cost of equipment and handling of chemicals are an additional barrier that small farmers are not willing to deal with.
	Increase the frequency of manure removal (daily or weekly)	» It is common practice to remove manure from concrete surfaces daily and weekly in corrals, which is then spread to dry in the sun before being hauled to fields. » It is unlikely that increasing this frequency would have a significant mitigation impact. Most facilities below this frequency lack the capacity and/or resources to increase it.
Manure treatment	Anaerobic digestion	» Technology is mature but requires a larger scale than available in Georgia. A minimum of 500 cows or 2000 pigs are necessary to operate a digestor (US EPA, n.d.), and Georgia's average farm size has between one and four cows and pigs (GEOSTAT, 2014). » Pooling manure from neighbouring farms is considered unrealistic considering the large number of farms that would need to participate, the relatively large distance between them, and the high equipment and logistics costs.
	Aerobic digestion	» High capital, operating and maintenance costs. It is quite energy intensive and requires manure to be previously separated (solid / liquids). » As for anaerobic digestors, this option requires larger size farms to make it economically feasible.
	Acidification (addition of acids to manure slurry ponds)	» Technology is still not mature and requires significant investment for tanks and the acids used (Jacobsen, 2015). » There also are concerns over safe handling of acids and uncertainty about the long-term impacts on soil (Jacobsen, 2015). » Most small-scale farms in Georgia do not have dedicated ponds to store manure.
Manure left on pastures	Manure left on pastures	» Not analysed in report, small likelihood of its management given how disperse manure is in the fields. » Georgia's pasturelands are mostly public, reducing incentives for farmers to invest in any type of infrastructure needed to facilitate the management of manure left on pastures.

Below, we include the analysis of the three prioritised measures, namely use of covers, composting, and the application of manure as fertiliser. These measures can be implemented separately, or in combination. Manure can be used directly to improve soil composition, and compost can also achieve this goal, although with a longer processing time. Covers can improve both the manure storage and composting process.

6.1. Manure storage – Use of plastic covers

Applicability Covers are a useful abatement option during both the manure storage and the composting process. Materials can vary between straw, wooden lids tarp, plastic covers or even roofs. Some materials are more relevant for Georgia, especially considering the high cost of wood. Benefits from covers are not evident, so farmers are not inclined to purchase them themselves.

Status In most Georgian farms, manure is stored next to stables in piles without any cover. Normally there is no bedding but feed residues such as maize straw is often mixed with manure. Flat concrete pads are becoming more common as it facilitates the cleaning process.

Emissions International studies indicate that plastic covers have the potential to reduce between 12% and 45% of methane emissions and up to 30% of nitrous oxide emissions (Clemens et al., 2006; Mohankumar et al., 2018). For this exercise, we assume full implementation of this practice by all farmers having cattle livestock and we estimate a reduction of between 145 and 160 $GgCO_2e$ in 2030. An important disclaimer for this estimate is that storage conditions are extremely relevant when it comes to defining the impact in emissions reductions. Generally, manure should be stored in cold, dry conditions to optimise emissions reduction. Further, warm and humid storage places could even reverse the effect and lead to higher emissions from manure storage.

Costs Wood is not a suitable material due to its high price in the region, but plastic covers can achieve the same results. As benefits are not easily visible even though the cost for plastic covers is not high, farmers have been reluctant to invest in them.

Unlocking The use of cover could not only contribute with reducing GHG emission, but also controlling odours. However, farmers are often not aware of these other benefits or of the moderate cost of implementing this practice. A strategy for education and awareness can improve the situation, coupled with pilot projects that provide covers to farmers. The expected relatively low costs of such a pilot program would most likely accelerate its uptake and reduce emissions in the sector.

Support needed The use of covers could be made a requisite for farmers applying for grants and subsidy programs from the government would be the most effective way of ensuring implementation. Similarly, capacity building programs and developing linked certification schemes as incentive would facilitate the uptake of this practice. This can be done through public funding or international cooperation, although the high number of small-scale farmers would most likely be the most important factor driving the costs.

6.2. Manure treatment – Composting

Applicability Composting of manure is a relatively straightforward process. Cow manure as a source of nitrogen mixed with a source of carbon like straw, peat or wood shavings can create compost in a few months depending on the conditions. It can be performed outdoors as long as the ground is firm and is not located near water sources as wells or streams. Some attention is necessary as the piles need to be turned at least 2 or 3 times during the composting process (NRCS, 2009). Lack of awareness and education on best practices and minimum requirements are the main barriers for composting, as well as the lack of scale for producing enough compost to access the compost market.

Status Composting is already performed by some Georgian farmers, although it is not always done under ideal conditions and farmers could benefit from concrete guidelines and best practices. Certification schemes can also help but are currently only done as a voluntary practice.

Emissions Several studies highlight that composting of organic waste can contribute to reduce emissions from manure management. Some even indicate composting can result in 90% less emission than the baseline scenario, depending on baseline practice (Luske, 2010; Pattey et al., 2005). For these calculations, we assumed that most of Georgia's manure is currently stored in stockpiles, which produces up to 1.46 times more emissions than composting manure. This is translated into an emissions reduction of about 160 $GgCO_2e$ in 2030, assuming full implementation of this practice by all farmers that have cattle livestock.

Costs The costs can vary depending on the setup. Compost piles can be placed in "sheds" with a roof, covered with tarp or plastic or even left outdoors. Piles can be placed in concrete pads or simply in firm, dry soil. Airing can be improved by running perforated pipes through the middle of the piles, although regular turning can also achieve aeriation with a tractor/loader or even a shovel if the pile is small enough. An education and awareness strategy can be developed within the public budget for rural development.

Unlocking Dissemination of best practices is the main need. Most farmers will have the necessary equipment so the selection of a suitable composting site and guidance for performing the basic tasks would facilitate access to this practice. A certification scheme, since it is currently only voluntary, can provide an incentive for farmers to improve the process or even market the produced compost.

Support needed Capacity building programs can provide the necessary information for farmers, and strategies for education and awareness can be developed with public or international cooperation funding.

6.3. Manure application as fertiliser

Applicability Applying organic fertilisers such as manure to the fields reduces the use and corresponding emissions of synthetic fertiliser on farms. This is translated in an economic saving for farmers as they reduce their demand for synthetic fertilisers while also contributing to increase in soil organic matter and soil quality. For its application to be most effective, farmers should take into account the 4Rs principle, which highlights the importance of applying the right nutrients, at the right time, right rate and right place to optimize crop yields and minimize nutrient loss.

Status Manure is already being used as fertiliser by Georgian farmers. Small-scale farmers who are not in a position to purchase fertilisers and invest in equipment for their application have been using manure to improve soil quality. However, the amount of organic fertiliser used per unit of agricultural area has been fluctuating between ~25-150 kg/ha since 2010. This fluctuation may indicate the need for further capacity training and awareness around good practices for the use of manure as fertiliser (GEOSTAT, 2021). Furthermore, the share of total agricultural area treated with manure as fertiliser has steadily decreased from 2% in 2010 to 0.9% in 2020 (GEASTAT, 2021). Thus, manure collection and management can be improved to better utilise the manure, and the dissemination of best practices can lead to improved soil conditions and reduced emissions.

Emissions Most of the mitigation potential of applying manure as fertiliser comes from the potential to replace the use of synthetic fertiliser, decreasing the emissions associated with its manufacturing, transportation, and application. This practice will not reduce emissions from manure management, but it can indirectly contribute to reduce emissions from synthetic fertilisers. Some international studies estimate that manure application to fields could reduce up to 10% of fertiliser use (Snyder et al., 2014), which is the assumption we took for these calculations. This translates into an emissions reduction of about 50 $GgCO_2e$. This reduction can potentially be higher if combined with good practices for application, considering that there is currently an excessive use of fertilisers by farmers in Georgia. However, if mismanaged, manure application to the fields could actually end up increasing emissions from nitrous oxide as well as CO_2 emissions from soils. Thus, it is extremely relevant to combine this practice with good training on the crops cycles and nitrogen needs to match those while also avoiding runoff e.g., by applying just before rain periods.

Costs Implementation costs are low, as it would mainly focus on awareness raising and further training campaigns to improve current practices and there would be no need for additional investment in new equipment. An indicative budget of roughly 100,000 EUR for such efforts, spread over three years, was already included in Georgia's Climate Action Plan (MEPA, 2021a). The selection of a good location for manure storage is key and might require some small cost adjustments. Covers can improve storage conditions and the combination of both measures would be beneficial, both for climate performance and cost effectiveness. The main factor influencing implementation costs would be the setup of a program to disseminate best practices. Such an education an awareness strategy can be developed within the public budget for rural development.

Unlocking Capacity building programs would be needed to disseminate best practices around manure management and its use as fertiliser. Additionally, this builds on the successful implementation of the two previous measures (use of covers and composting) as these would contribute to having more manure readily available to be applied to the fields.

Support needed Finance for capacity building programs would be required, whether through farmers associations or directly funded by government institutions. Initiatives like this can often be funded through international cooperation but can also be developed with public funds if prioritised within rural development strategies.

7. Recommendations and conclusion

In this report we identified three mitigation measures for manure management emissions in Georgia. These include **the use of covers when storing manure, composting and manure application as fertiliser,** all focused on cattle farms only, given its significant contribution to national manure management emissions. The three prioritised measures are, however, what is referred to as “end of the chain” measures; these practices are not addressing the levels of activity (amount of manure produced) or the emissions intensity of the activities (level of emissions from manure) but rather have a “circular economy” approach to integrate the produced waste into other farming processes.

Several other measures were taken into account but finally considered less relevant in the Georgian context for the short term (see Table 1). The two main factors for disregarding several of the other manure management practices where that most farming is done at a very small scale and that a big share of emissions come from manure left on pasture, or “unmanaged” manure. The former limits the ability for investment in new equipment or technology, and the latter complicates collection as manure is spread over vast amounts of public land.

Emissions from manure left on pastures are difficult to be managed given how disperse manure is in the fields. Therefore, this report focused on addressing emissions from manure (in farm) management from dairy and non-dairy cattle. However, there are opportunities that should be further explored and researched that could help implement good practices around it while reducing emissions. For example, summer pastures leased to farmers by the government, offer an interesting opportunity as manure is accumulated in the fenced shelters where animals spend the night. The state could provide some basic infrastructure and develop strategies so farmers can at least manage manure in these temporal shelters while they lease the land.

This study finds that the widespread use of covers can reduce emissions by up to 145-160 $GgCO_2e$ in 2030. This would require government’s support through, e.g., requiring farmers that apply for grants and subsidy programs to use plastic covers. Capacity building efforts are also needed to increase farmer awareness on the benefits of using covers and best practices on location and conditions for manure storage, as well as potentially providing small-scale farmers with covers as part of pilot incentive programs.

Similarly, widespread and effective composting, which in some cases can require the use of covers, could reduce emissions by up to 160 $GgCO_2e$ in 2030. A similar approach with dissemination of best practices and capacity building can be enough to increase composting practices, as the technology and infrastructure requirements are relatively low and currently accessible to farmers.

Using compost or manure to improve soil quality can reduce synthetic fertiliser use, which does not reduce manure management emissions directly but contributes to reducing emissions from synthetic fertilisers. While fertiliser emissions are not counted under the manure management category, reducing these can reduce the climate impact of the agriculture sector as a whole and it is aligned with one of the three goals of the Rural and Agricultural Development Strategy of Georgia. We estimate a reduction of about 50 $GgCO_2e$ from substituting synthetic fertilisers with organic fertilisers (i.e., manure).

The combined three mitigation options analysed in this report could lead to a reduction of up to 300 – 320 $GgCO_2e$. That represents a potential reduction of just under 10% of the sector’s emissions, compared to the estimated ~1% reduction given for the agriculture sector GHG emissions reduction in 2030 with CSAP measures (MEPA, 2021a). However, all emissions reduction calculations are assuming full and widespread implementation of these practices, which have a degree of overlap. Therefore, the reduction potential of implementing these three practices (to different extents) is expected to result in a lower final emissions reduction than the sum of the three. Further, these estimations are meant as a first indication of the maximum mitigation potential that can be achieved through these prioritised measures.

In general, capacity building on manure management could include best practices on all three of the measures prioritised, with some pilot projects providing covers or other equipment to expand composting practices or manure use in fields. A comprehensive strategy to reach as many small-scale farmers as possible is likely to yield results and have other environmental and economic benefits.

Considering the expected growth and industrialization of Georgian livestock farming (expected to reach 1.4 million cattle by 2030, from the current 900,000), other mitigation options that look at improving productivity and efficiency and reducing emissions intensity of activity should be considered. An increasing number of animals will lead to higher emissions unless further measures are explored and implemented that can reduce emissions at the activity or intensity levels. Some of the options to reduce manure management emissions that were evaluated were not likely to be implemented in the short term because of a lack of infrastructure and high capital costs. This is the case for example for anaerobic digestion lagoons. Such measures might be considered for the medium to long term, but investments and capacity building must start as soon as possible so its mitigation potential can be realised in the longer term.

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