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Study on Mitigation Opportunities and Mainstreaming in the Agriculture

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The objective of this "Study on Mitigation Opportunities in the Agriculture" is to assess the mitigation potential of Agriculture sector in Armenia for elaboration of the Long-Term Low Emission Development Strategy focusing on the key sources of greenhouse gas emissions and to develop recommendations on policies and measures for mainstreaming climate change mitigation practices.

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List of Abbreviations

AD	Anaerobic digestion
CC	Climate change
CO_2	Carbon dioxide
CH_4	Methane
EF	Emission factors
EU	European Union
FAO	Food and Agricultural Organization of United Nations
FSN	Synthetic N fertilizer
GAC	General Agricultural Census
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
CH4	Methane
MoE	Ministry of Environment
N	Nitrogen
N_2O	Nitrous oxide
RA	Republic of Armenia
SDG	Sustainable Development Goal
SCRA	Statistical Committee of the Republic of Armenia
UN	United Nations
UNCT	UN Armenia Country Team
UNFCCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme

Preface

Climate change continues to intensify the occurrence and scale of natural disasters. Over the past decades, the impact of climate change has intensified in Armenia, with almost all climatic variations occurring and driving the temperature levels up.

Armenia is a signatory of Paris Agreement on Climate Change and an active implementer of various initiatives aimed at improving climate policies and legislation that contribute to its low emission and climate resilient development. The Paris Agreement has initiated a process where states enhance their efforts to limit emissions and augment resilience aimed to achieve the long-term temperature objective of the Paris Agreement. The Republic of Armenia (RA) Government partners with the UN Armenia Country Team (UNCT) to identify priorities which will be on the agenda of global sustainable development. Sustainable Development Goals (SDG) 13 "Climate Action" is aimed at taking urgent actions to combat climate change and its impacts.

This Study is implemented in the framework of EU4Climate program, which is aimed at helping the six countries of European Union (EU) Eastern Partners, namely Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine to take action against climate change. It supports the countries in improving climate policies and legislation that contribute to their low emission and climate resilient development and their commitments to the Paris Agreement on Climate Change.

The Study has examined the Agricultural sector in Armenia, which is the second largest producer of greenhouse gas (GHG) emissions, as a result of farm related activities such as enteric fermentation, manure management, fertilizer application to crops and many more, with carbon dioxide representing the largest share of emissions. Direct emissions from the Agriculture sub-sector made up 18.5% of country's total emissions in 2017. Direct agricultural emissions include methane (CH4) emissions from enteric fermentation of the livestock, manure management and biomass burning, as well as nitrous oxide (N_2O) emissions from manure management and direct and indirect emissions from managed soils following additions of urea-containing fertilizer and crop residues.

This Study focuses on the GHG emissions from the key sources (enteric fermentation, manure management, fertilizer application to crops) and develops recommendations on policies and measures for mainstreaming climate change mitigation practices in Agriculture sector of Armenia.

As a result of the Study, mitigation opportunities and recommendations on policies and measures for mainstreaming climate change mitigation practices in Agriculture sector in Armenia are presented which are based on research and analysis of different development scenarios for reducing threats and risks associated with it.

The conclusions reached in this report are of consultative nature and are considered appropriate for the time of its preparation. The output is aimed at the presentation of mitigation opportunities and recommendations on policies and measures for mainstreaming climate change mitigation practices in the Agriculture sector of Armenia.

Executive summary

Agriculture is one of the leading economic sectors in Armenia, securing around 12% of the GDP and 24.3% of the employment. Agricultural production needs to grow in response to the growing demand, however, climate change represents a serious challenge, which is and will continue to affect from and impact on the agricultural activities.

In Armenia, agriculture sector is contributing to 18.5% of the GHG emissions (2017). Taking into account the projected agricultural production volumes outlined by "The Strategy of the Main Directions Ensuring Economic Development in Agricultural Sector of the Republic of Armenia for 2020-2030"- the main document to define sector's development trends, if current trends in agriculture production and management approaches are retained in future, the level of GHG emissions from this sector will increase by 91.8% by 2030. Livestock will be responsible for 58.7% of those emissions and land management will be responsible for another 41.3%. Efforts to mitigate the climate change in Armenia should be considered to ensure economic and environmental sustainable development.

The Study focuses on mitigation activities, which based on the best practice analysis, are most applicable to the context of Armenia. A review of various measures and their technical analysis proved that there is high potential to reduce the level of emissions from Agriculture sector in Armenia.

The "Mitigation scenario" considers application of the following international best practices in livestock management in Armenia by 2030:

- improving breeding and genetics;
- improving feeding and management.

This will allow only 28% (1,364 Gg CO_2 eq) GHG production increase from Livestock compared to 2017 in contrast with 108% (2,212 Gg CO_2 eq) if no mitigation actions are taken. To achieve this target, the following recommendations are made:

Policy and legal • Elaborate a national program on climate change mitigation in agriculture sector. • Introduce Government support program for enhancing the introduction of Swiss breed cattle to the country. • Introduce Government support program for enhancing the introduction of artificial insemination for breeding Swiss breed cattle in the country. • Develop policies and incentivize in the area of introduction of new, higher productivity cattle breeds in the country.	***Institutional*** • Establish an institutional set-up across sectoral national bodies to coordinate the development and implementation of climate change mitigation in agriculture.
Capacity Building • Creation of a centralized platform for data and knowledge interchange on climate change mitigation as well as adaptation, including depositary of case specific mitigation (adaptation) models and local and international good practices to be utilized to contribute to GHGE mitigation. • Strengthen national institutional capacities of technical knowledge and expertise on climate change mitigation and adaptation.	***Technical and technological*** • Introduction of efficient & robust animals and improved feeding. • Work with relevant funding organizations and donors such as Green Climate Fund, Global Environment Facility, the World Bank, Asian Development bank, KFW, EU, other development partners, donors, private sector, etc., in support of

• Strengthen national institutional capacities and technical facilities to generate, collect, analyze and use data information that enhances their ability to address climate change adaptation and mitigation. • Organize awareness raising campaigns among farmers, local public institutions and other beneficiaries on climate change mitigation and adaptations. • Strengthen capacities of farmers through commonly used approaches such communication, training, practical on-job training demonstration farms, farmers' field schools and establishing producers' networks for knowledge sharing. Share knowledge and information through ICTs. Specific areas will include enhancing the knowledge of farmers regarding rearing and maintenance of new breeds and optimal feeding strategies (including advise and training, on-job training, demonstration, etc.). • Strengthen capacities of agricultural advisory, extension and support services which includes facilitates practice change for mitigation and production enhancement, by providing access to good practices and technologies and building capacity to implement them. • Establish close cooperation between agri-food industry, breeding organizations, feed producers and research institutes.	implementation of Climate Change mitigation actions in the field of agriculture. • Develop and introduce efficient animal feed and forage management practices system. • Introduction of anaerobic digestion. • Pilot programmes in areas where most benefit is expected, such as changing animal breeds and providing improved feeding regime in selected leading animal farms or organization of high-quality feed production operations in the country, including efficient and modern methods of high value feed crop growth and harvesting and storage, that will subsequently result in increased production volume and reduced losses of feed nutrient value.

Under the mitigation scenario, the GHG emission reductions from land management according to international best practice review, will be achieved through:

- Increasing carbon sequestration;
- 4R Nutrient Stewardship framework

The mitigation potential of GHG production from lands, that considered soil carbon sequestration and reduced synthetic fertilizer use by 2030 was not possible to quantify due to lack of quantitative data. Yet, to achieve reduced GHG emissions from land management, the following recommendations are made:

Policy and legal	***Institutional***
• Expand the existing state support programme/ introduction of modern irrigation systems. • Promote introduction of crop rotation including legumes crops in the rotation. • Introduce and expand the existing state support programmes on promoting production of leguminous crops on arable land • Develop policies in the area of AD installation and use in the country. • Develop regulations in the area of environmental impact of agricultural farms.	• Introduce mechanisms for promotion of wide use of crop rotation systems. • Introduce mechanisms for decreasing the import and use of urea-based fertilizers. • Introduce mechanisms for promotion of production of annual and perennial leguminous grass crops. • Introduce mechanisms including Government support as well as donor support to promote uptake of fertilizer application machinery (for example fertilizer drillers).
Capacity Building	***Technical and technological***
• Introduce the subsidy and/or support projects for farmers involved in conservation agriculture.	• Introduction of Conservation Agriculture.

• Establish agricultural machinery pools for introduction and promotion of conservation agriculture. • Introduce technology transfer and capacity building through establishment of demonstration sites and on-job training in cooperation with the research centers. • Raise capacities of the farmers through training and awareness raising campaigns. • Build the technical capacities of the public and private advisers, the relevant staff of scientific and research institutions to transmit and disseminate quality information on conservation agriculture to farmers. • Strengthen capacities of farmers, agricultural advisory, extension and support services, technically competent institutions, authorities, including staff of agrochemical services on plant nutrient management and fertilizer use. • Organize awareness raising campaigns among farmers, local public institutions and other beneficiaries on sustainable soil and water management, crop rotation and GAP on fertilizer management. • Increase awareness and capacity of farmers on expansion of sown area of leguminous crops on arable land • Create professional workforce and expertise for AD; • Improve the knowledge of farmers regarding AD (including advise and training), specifically for smallholders. • Organize awareness raising campaign for the introduction of AD for manure management. • Demonstrate and pilot AD systems.	• Reducing GHG emissions from nitrogen fertilizer management. • Expand the sown area of leguminous crops on arable land. • Develop and introduce good agricultural practice (GAP) on plant nutrient management and fertilizer use. • Develop guide(s) on good agricultural practices on implementation of scientifically grounded crop rotation systems for different climatic zones, soil, crop types, etc. • Application of fertilizers should be based upon soil analysis and/or recommendations of technically competent institutions, authorities or personnel. • Introduce precision farming technologies to enhance efficient use of inputs, including fertilizers. • Invest in technological apparatus and adequate infrastructure for manure collection, storage and AD.

Methodological approach

Methods of calculation

Calculation methods used in this Study were chosen in accordance with 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories[1]. This provides methodological approach for estimating national inventories of anthropogenic emissions based on the sources and their conversion to GHG. GHG emissions from agriculture sector are reported in National Communications of Armenia and National Greenhouse Gas Inventory Report of the Republic of Armenia developed under the framework of UNFCCC. The first National Communications was submitted in 1998 and there are 4 National Communications so far, covering the period from 1990-2017.[2] starting from 1st NC reported in 1998.

This Study is mainly based on the 2006 IPCC guidelines developed in Volume 4 "Agriculture, Forestry and Other Land Use" as the subject area is the emissions from Agriculture sector. However, it also utilizes any information which is useful for the sector analysis and is interlinked with the aforementioned other Volumes.

Specific method of calculation and scenario analysis are presented at the beginning of each corresponding chapter.

[1] "Guidelines for National Greenhouse Gas Inventories", IPCC, 2006. https://www.ipcc-nggip.iges.or.jp/public/2006gl/
[2] 4th National Communication of Armenia, under UNFCCC, 2020

Data collection

The Study is also based on the "National Greenhouse Gas Inventory Report of Armenia" 1990-2017 (NIR report) developed by RA Ministry of Environment based on the 2006 IPCC Guidelines.

During the Study, the main sources of information and data collection have been:

- Chapter 4.3. Agriculture, Forestry and Other Land Use Sector of the NIR report 1970-2017, as well as other sectoral chapters. These provide insights for the Agriculture sector review, including historical data on emissions and livestock headcount.
- The Strategy of the Main Directions Ensuring Economic Development in Agricultural Sector of the RA for 2020-2030.
- Historical data published by the Statistical Committee of the RA.
- Professional literature on livestock activity data.
- Professional literature on cropland activity data.
- IPCC Emission Factor Database, etc.

Expert judgement was used for the choice of the most appropriate data inputs and for developing data estimates required for conducting the analysis.

Uncertainties

According to the 2006 IPCC Guidelines[1], the uncertainty associated with populations will vary widely depending on source but should not exceed the ± 20% range. The possible uncertainty of cattle population is estimated from ±8% to ±10% due to the existing deviations in data on livestock population.

Quality assurance/control and verification

Quality assurance/ quality control measures for the current study have followed the protocol of the National Greenhouse Gas Inventory Report of Armenia 1990-2017. Data completeness and accuracy were assured by consideration of all the categories of animals managed in the country. The data collection, aggregation and processing methods and approaches and their correspondence to the actual situation was also analyzed.

In the framework of the Study, the Tier approach advised in 2006 IPCC Guidelines was used, which represents a level of methodological complexity. Three tiers are provided by 2006 IPCC Guidelines.

Tier 1 is the basic method, where key source categories are identified using a pre-determined cumulative emissions threshold. The pre-determined threshold represents an evaluation of several inventories and is characterized with a 90% of inventory uncertainty level covered by key source categories.

Tier 2 is the intermediate complexity level. This tier is applied in order to identify key source categories if there are nationally derived source-level uncertainties available. Tier 2 approach is a more detailed analysis and it builds on the Tier 1 approach. In this tier, the number of key source categories that need to be considered is likely to be less. For deriving to the level Tier 2, instead of applying the pre-determined cumulative emissions threshold, the results of the Tier 1 analysis are multiplied by relative uncertainty of each source category, which represent 90% of the uncertainty contribution.

Tier 3 is the most demanding tier in terms of complexity and data requirements This tier assumes application of higher-order methods including models. It can utilize data tailored to address national circumstances. Tier 3 provides higher level of certainty as compared to the lower-level tiers and can have a closer link between biomass and soil carbon dynamics.

Tiers 2 and 3 are also referred to as higher tier methods with higher level of accuracy. [3]

[3] Ibid.

1. Armenia: country overview and climate change

Climate change is one of the key issues of our time. It causes changes in weather conditions, leads to intensification of natural disasters and creates risks for human’s social, economic and political activities.

1.1. Country overview

Background

The Republic of Armenia (RA) is located in the north-eastern part of Armenian Highlands of Western Asia, between the Central Asia and the Caucasus (the inter-river basin of Kura and Araks rivers). The total area of the country is 29,743 square kilometers. Armenia borders Georgia to the north, Azerbaijan to the east, Turkey to the west, and Iran to the south.

Source: Geopolitics.com,
Link: http://english.geopolitics.ro/georgia-armenia-and-azerbaijan-a-brief-geopolitical-analysis/

Landscape

The average altitude is 1,800 m above sea level (77% of the country is located at an altitude of 1,000-2,500m above sea level). 36% of the territory of the RA is covered with mountains and plateaus. Armenia is a mountainous country, the altitudes of which varies between 375-4,090m above sea level, the lowest point is the bottom of Debed River, and the highest point is the top of Mount Aragats.

Territorial division

The basis of the administrative-territorial division in Armenia is the RA Law "On administrative-territorial division of the RA" and “The law of the RA on local self-governance”. According to the Law, the territory of the RA is divided into 10 marzes (regions) and the city of Yerevan. As of 2020, the number of communities was 502 (the number of settlements was 1,004)[4], including 49 urban communities, as well as the city of Yerevan with 12 administrative districts.

Population

The population as of January 1, 2021 was 2,964 thousand people: the urban population - 1,896 thousand people (64%), and the rural population - 1,068 thousand people (36%). The average population density is 100 people per square meter.

Climate

The climate in Armenia is quite dry, the average annual precipitation being 592 mm. Annual precipitation also varies in a fairly wide range, from 200 mm (arid areas) to 1,000 mm and above (in the highlands). The maximum precipitation is observed in high mountainous wetlands - 800-1100 mm, recorded in the period from May to June. In the Ararat Valley and in the lowlands of Syunik, the level of annual precipitation reaches

[4] Number of De Jure Population of the Republic of Armenia as of October 1, 2020, SCRA, 2020
Link: https://www.armstat.am/file/article/nasel_01.10.2020.pdf

200-250 mm. In summer, precipitation is at low level in the lowlands (32-36 mm). For example, in the Ararat Valley, precipitation is at 32-36mm level on average[5]. The rainy season is observed from April to May.

The distribution of snow is uneven. There is little snowfall in the Ararat Valley, while in the highlands there is a stable layer of snow for 5-6 months, the height of which sometimes reaches 2 meters. Changes in the direction of wind is due to the difficult terrain. For this reason, different wind directions and speeds are observed. The strongest wind is observed in the highlands in winter. In summer, the mountain wind appears in the lowlands.

Temperature

The long-term average temperature in Armenia is 5.5^{0}C. The absolute minimum temperature recorded is (-42)^{0}C (in 1961), and the absolute maximum temperature recorded is +43.7^{0}C (in 2011). The average temperature in the highlands in June-August is 10^{0}C, and in the lowlands it is 24-26^{0}C. The average temperature in January depends on the altitude of the place. It fluctuates from (-13)^{0}C to +1^{0}C. January is the coldest month of winter, with an average temperature of (-6.7)^{0}C[6].

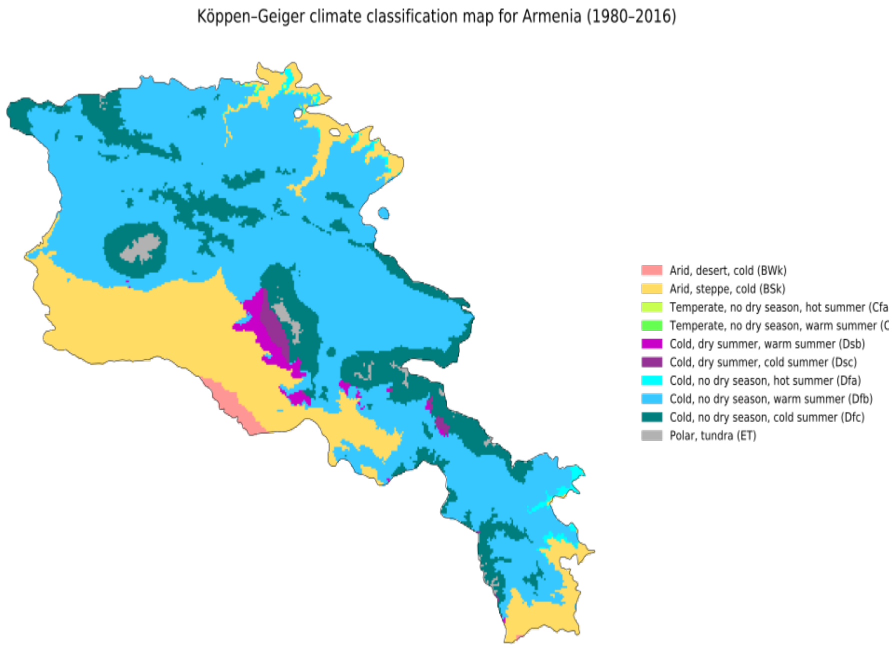
Climatic zoning

Armenia has a well-defined climate diversity and upward zoning. There are 6 climatic zones on the territory of the country: dry subtropical, semi-desert, steppe, forest, alpine and cold high mountain.[7]

The Republic is divided into 9 agricultural agro-climatic zones, which are based on the division of the area according to the similarity of climatic features, which determine the growth and yield of plants.[8]

According to the RA Government 2019 report on the availability and distribution of land resources, the agricultural lands make up 66.7% of the country's territory, the settlements - 5.1%, the forests - 11.2%, and specially protected areas - 11.3%.

Individuals own 18.1% of the land resources, legal entities own 1.2%, 34.5% and 46.2% correspondingly represent community and state property.[9]



Source: Beck et al., Present and future Koppen-Geiger climate classification maps at 1-km resolution, Scientific Data 5:180214, doi:10.1038/sdata.2018.214 (2018)

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[5] Armenia's Third National Communication on Climate Change, RA Ministry of Nature Protection, 2015 Link: http://www.nature-ic.am/wp-content/uploads/2013/10/3.Armenias-TNC_2015-ARM.pdf

[6] Armenia: Road Map for the Development of Climate Change-related Statistics, SCRA, 2020 Link: https://armstat.am/am/?nid=787

[7] Armenia: Road Map for the Development of Climate Change-related Statistics, SCRA, 2020. Link: https://armstat.am/file/doc/99518218.pdf

[8] The Impact of Climate Change on Land Degradation and Fertility in Armenia, United Nations (UN) Food and Agriculture Organization (FAO), 2017, Government decree N1379-N, 03 October 2019. dcf.am/hy/publications

[9] RA Government decree N1379-N On approval of the 2019 report on the existence and distribution of the land fund of the RA (Land Balance), RA Government, October 03, 2019. http://www.irtek.am/views/act.aspx?aid=101871

Landscape and biodiversity

The landscape of the country is a combination of mountain ranges, plateaus and valleys, which has a great impact on the country's agriculture. Most of the cultivated lands are located at an altitude from 600m to 2,500m height. Most of the agricultural lands are generally fertile.

Armenia has a rich biodiversity. More than 4,500 species of mushrooms, about 9,000 low class and high-class plants are registered in the country, the density of those make Armenia one of the leading countries-about 107 species per 1sqm. The fauna includes about 17,500 species of invertebrates and vertebrates. The gene pool contains not only many endemic species, cultivated - wild relatives of domesticated species, but also valuable useful species[10].

1.2. Climate change and agriculture in Armenia

The role of climate in agriculture

As already mentioned in the previous sections, 36% of the population of Armenia or 1,069 thousand people is rural population. Agriculture provides 11.7% of the gross output of the Republic of Armenia economy (2020). Livestock and crop are leading branches in agriculture, both considered in this Study. Agricultural sector has a significant impact on climate change.

In Armenia, climate change is expected to lead to reduced crop production in the agricultural sector, deterioration of agricultural lands, increased demand for irrigation water, change in the structure of the ecosystem, emergence of new pests, diseases and safety risks[11].

According to the “National Greenhouse Gas Inventory Report of Armenia 1990-2017”, the GHG emissions from agriculture sector in 2017 accounted for 18.45 % of total emissions in Armenia.

Therefore, being the second by share sector in GHG total emissions, the mitigation policy for the sector has to be developed. The purpose of this Report is to assess the prospects for agricultural development, design the profile of agricultural emissions, assess climate change mitigation opportunities in line with sector development prospects and develop long-term mitigation targets that can become an integral part of Armenia's long-term low carbon development strategic plans.

[10] RA Government decree N 1059-A on Strategy of Specially Protected Areas, consideration of the state program in the field of protection and use, RA Government, September 25, 2014
Link: https://www.arlis.am/DocumentView.aspx?DocID=93166

[11] “Armenia assessment of agricultural sector vulnerability to climate change and climate change adaptation: legal and institutional framework”, Center for Agribusiness and Rural Development (CARD), 2019. Link: http://nature-ic.am/Content/announcements/12692/NAP_Agriculture%20assessment%20report_arm_FINAL.pdf

2. Agricultural sector in Armenia

2.1. Overview

Although the share of agricultural products in the structure of Armenia's GDP has been gradually decreasing, it remains one of the key sectors of the country's economy.

Agriculture sector is one of the leading and strategic economic sectors of Armenia. It is important in terms of the country's economic development prospects, formation of the gross domestic product, ensuring macroeconomic stability, food security and foreign trade balance. The role of the sector is strongly emphasized for balanced territorial development, employment and income generation in rural areas, overcoming poverty, raising the standard of living, and, importantly, ensuring food security of the population. Agriculture sector is also a major source of raw materials for the food industry, a sector with one of the highest potential for export.

In 2020, agriculture sector contributed to 11.7% of the GDP, of which 47% composed crop production and 53% - cattle breeding. In 2020 compared to 2019, there was a 1.4% growth in agriculture sector in contrast to 7.6% decline in GDP. This growth was driven by growth in the subsectors of crop and livestock production - 2.3% and 0.6%, respectively.

In 2019, there was a 4.2% real decline in agriculture sector in contrast to 7.6% growth in GDP. Gross agricultural output (at current prices) in 2020 amounted 819 billion AMD.[12][13]

Table 1: Main macroeconomic indicators and gross agricultural output of the RA, 2009-2020[14]

Indicators	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
GDP growth rate, %	-14.1	2.2	4.7	7.2	3.3	3.6	3	0.2	7.5	5.2	7.6	-7.6
Share of agriculture in GDP, %	16.7	16.8	19.9	17.9	18.4	18.1	17.3	16.4	14.5	13.7	11.6	11.7
Gross agricultural output, at current prices, billion AMD	552	637	795	842	919	983	945	879	909	893	853	819
Annual real growth, %	*-0.5*	*-13.6*	*13.9*	*-0.5*	*7.1*	*6.3*	*8.4*	*-5.2*	*-3*	*-7.6*	*-4.2*	*1.4*

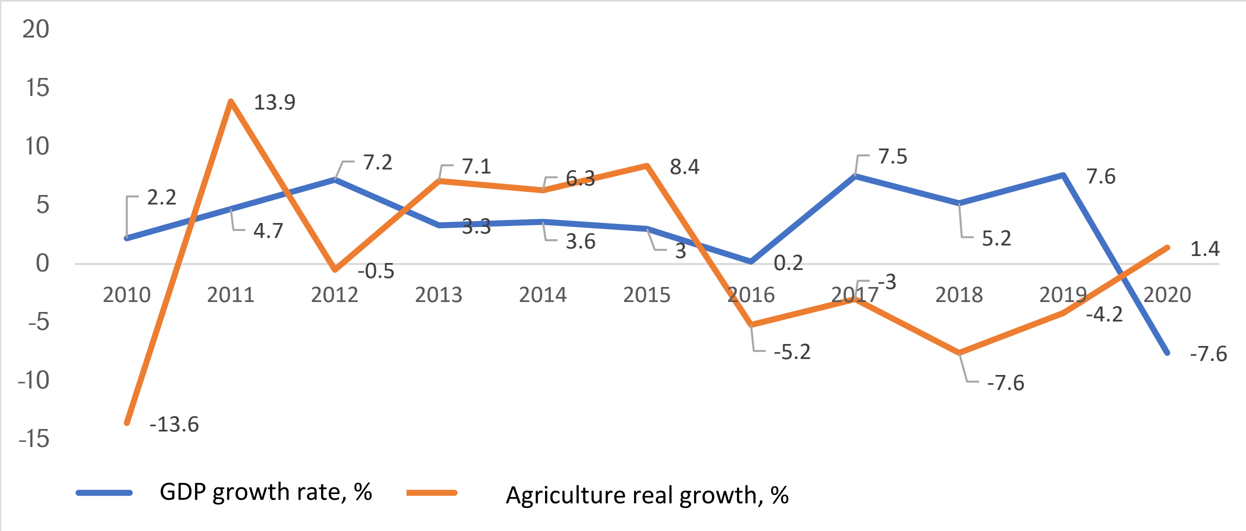
The decline in the share of agriculture sector is explained by growth in other economic sectors, its low efficiency and low profitability in certain branches, low volume of exports and fluctuations in market prices, as well as the reduction of sown areas of major field crops and reduction of agricultural animals in recent years (2017-2020). The short-term results of the sector development are also dependent on year-specific climatic conditions.

[12] The main macroeconomic indicators characterizing the RA economy 2017-2019 (January-December)", National Assembly of the RA, 2021.
Link: http://www.parliament.am/budget_office.php?sel=reports_and_statements&action=references&lang=arm

[13] The main macroeconomic indicators characterizing the RA economy 2018-2020 (January-December)", National Assembly of the RA, 2021. Link:
http://www.parliament.am/budget_office.php?sel=reports_and_statements&action=references&lang=arm&id=377

[14] "Statistical indicators, the volume of gross agricultural output in million AMD", SCRA, 2020.
Link: https://www.armstat.am/am/?nid=12&id=03001

Figure 1: The annual GDP and agriculture growth rate, 2009-2020



2.2. Agriculture sector in Armenia

2.2.1. Main characteristics of agriculture sector in Armenia

Food security

Since 2001 the level of self-sufficiency in basic food products in Armenia and access to general food have significantly increased as a result of increased efficiency in agriculture sector.

Nevertheless, there is still dependence on basic food imports. In 2019, the level of self-sufficiency for the most important food products in the country was about 52.5% (according to the average energy value of the diet), which is lower by 2.5% as compared to 2017.

According to 2019 data, the degree of self-sufficiency is high in potatoes (101.1%), fruits (104.0%), grapes (103.6%), vegetables (102.4%), eggs (100.0%), fish (113.1%) beef (90.4%), mutton (113.8%) and milk (84.3%). Wheat (25.9%), legumes (38.2%), vegetable oil (1.5%) and other types of meat are still at a low level of self-sufficiency[15]. In 2019, for the first time in Armenia, the Global Food Safety Index was calculated: 57.1. In particular, food availability index was 51.7, accessibility - 66.2, quality and safety - 45.4[16]. On this indicator, Armenia ranked 76th among 113 countries in the world[17]. At the event of "Food Security in Armenia. Politics over the years, market functionality, supply chains" (February, 2021), it was noted that Armenia has improved its position and moved from 76th to 48th place[18].

Overall, these circumstances make Armenia vulnerable to changes in foreign markets and economies, which poses a threat to food availability, especially in the event of an emergency.

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[15] Food security and poverty, 2019 January-December, SCRA, 2020.
Link: https://armstat.am/file/article/f_sec_4_2019_3..pdf

[16] Food security, RA Ministry of Economy, 2019,
Link: https://www.mineconomy.am/page/1333

[17] Global food security index, https://foodsecurityindex.eiu.com/index, Economist Intelligence Unit,

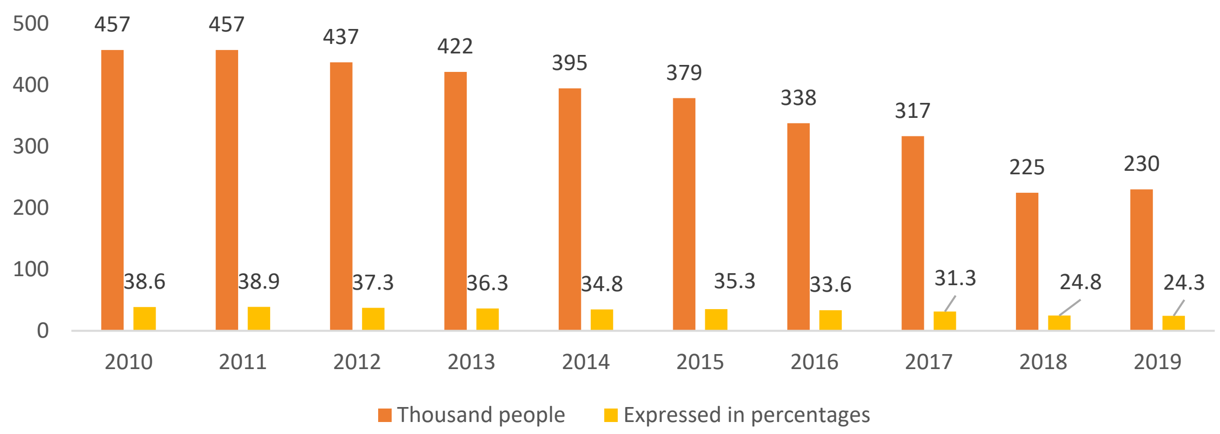
[18] News, RA Ministry of Economy, 2021.
Link: https://mineconomy.am/news/2178?fbclid=IwAR0QW7VK06AXFbMprhrYLbP2s7d75Pq-j1I_1xWHBjyPhr18Y0dJgg_H3oo

Employment in agriculture sector

Currently, more than 36% of the population of Armenia (1.07 million people) lives in rural areas. In recent years, this indicator has a tendency to decrease. In particular, during 2014-2019, the population of the villages has decreased by 30.8 thousand people or by 3%, which is conditioned by internal and external migration. According to the Statistical Committee of the Republic of Armenia (hereafter SCRA), in 2019, the workforce in Armenia comprised 1,167 thousand people, of which 947 thousand were employed and 221 thousand were unemployed (18.9%)[19].

Agriculture is one of the priority sectors providing employment in Armenia. In 2019, 230 thousand people or 24.3% of the employed population of the country was engaged in agriculture (Figure 2).

Figure 2: Employment in agriculture, 2010-2019



The number of people employed in agriculture sector has been decreasing year by year. This is mainly due to emigration from rural areas and the development of other sectors of the economy.[20]

2.2.2. Agriculture sector by type of activity

The extensive nature of crop and livestock sectors is reflected in the direct linkage of the increase and decrease in the production of crop and livestock products in relation to the change in the sown areas and the number of livestock.

The crop and livestock production sectors are important for agricultural development and contribute to the country's food security. In 2009-2014 period, the ratio of gross output of crop and livestock sectors expressed in average prices, on average, was 60% and 40%, respectively. However, the share of the crop production within the structure of agricultural output has decreased from 550 billion AMD (in 2015) to 384 billion AMD (in 2020). At the same time, the gross output of the livestock sector increased from 395 billion AMD (2015) to 434 billion AMD (2020). At present, the share of the livestock sector slightly exceeds that of the crop sector. The share of the former in 2018, 2019 and 2020 was 53.4%, 51.9% and 53.1%, respectively (Table 2).

[19] Employment, Socio-Economic Situation of RA, SCRA, January-March 2020.
Link: https://armstat.am/am/?nid=82&id=2257

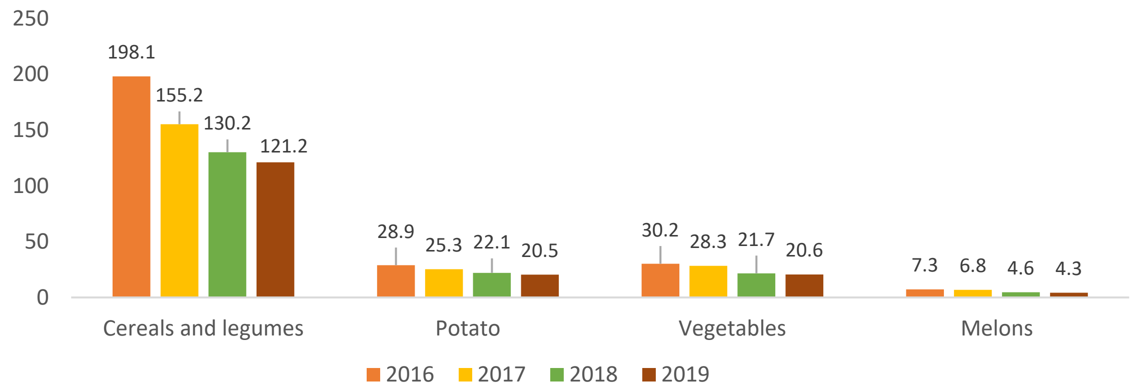
[20] The difference of 2018 and 2019 indicators in comparison with the previous years is conditioned by the application of the new methodology of labor market statistics by the SCRA.

Table 2: Gross agricultural output by sectors (at current prices, billion AMD) [21]

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	552.1	636.7	795	841.5	919.1	983	945.4	878.5	908.6	892.9	852.8	819.3
Out of which												
crop production	346.7	392.7	465.1	516	572.8	595.2	550	486.7	469.3	415.8	410.4	383.8
Cattle breeding	205.4	244	329.9	325.5	346.3	387.8	395.4	391.8	439.3	477.1	442.4	435.5

The decline of the crop sector is mainly due to the reduction of sowing areas, as well as unfavorable climatic factors. In 2018 and 2019, the sowing areas fell by 111 and 126 thousand ha, respectively, as compared to year 2016. In 2019, compared to the previous year, the sowing areas of the main crops decreased by about 5-9% (cereals - 6.9%, greens - 6.6%, vegetables - 5.1%, potatoes - 7.2%) (Figure 3).

Figure 3: Structure of main field crops, thousand ha (2016-2019)



As a consequence, in 2019 compared to the previous year, a decline in the gross harvest of the main agricultural crops was registered, except for the vegetable crops and grapes. Thus, the gross yield of cereals and legumes decreased by 41.2%, fruits and berries - by 15.5%, potatoes - by 2.7%, vegetables - by 1.1%. On the other side, the gross grape harvest increased by 21% to 217 thousand tons (Table 4).

The decrease in livestock production was mainly due to the decrease of the number of agricultural animals and receptively decrease of livestock products. For example, in 2020 the number of cattle was reduced by about 11.7%, compared to 2017 and number of sheep and goats reduced by 8.9%. The production of meat by 0.8%, milk by 4.3%, eggs by 0.85% and wool by 4.9% (2019 compared to 2018).[22]

Crop production

The crop production provides not only primary agricultural products, but is also the main supplier of the products for processing industry as well the main source of animal feed. Crop production in the country includes production of field crops, vegetables, fruits, berries and grapes, as well as other crops. Almost half of the sown areas is used for cereals and legumes, mainly winter wheat and barley. The share of the legumes

[21] “The main indicators of agriculture by regions, indicators and years”, SCRA, 2019. Link: https://armstatbank.am/pxweb/hy/ArmStatBank/ArmStatBank__6%20Agriculture,%20forestry%20and%20fishing/AF-3-2019.px/?rxid=3ba1631c-352e-46e0-924a-62e4b284bd7a

[22] Food security and poverty, 2019 January-December, SCRA, 2020. Link: https://armstat.am/am/?nid=82&id=2238

is less than 1% (Table 3). Potato is one of the main crops for the farmers especially in mountainous regions and around 10% of sawn areas is occupied by potato.

Vegetable crop production is organized in open and protected areas such as greenhouses, etc. The main vegetable crops cultivated in Armenia are tomato, pepper, eggplants, cabbage, carrots, etc.

Fruit and grape production are the most profitable elements of the cropping pattern in Armenia. Due to the history and the range of soil-climatic conditions of Armenia, the fruit production is rich and diverse. The range in altitude of the country and variety of soil-climatic conditions have created conditions for the production of different kinds of fruits such as apple, peach, apricot, plum, cherry, walnut, etc. Nowadays, fruit industry in Armenia is popular because of high fruiting potential of the orchards and high nutritional value of the fruits. Due to the perceived good taste, fruits are used both fresh and processed.

Table 3: Areas of major agricultural crops and perennial plantations yield [23]

	Area (thousand ha)							Yield (planting areas/ha) *						
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Sowing area, total	**318.1**	**332.8**	**337.5**	**353.4**	**294.5**	**242.3**	**227.9**	-	-	-	-	-	-	-
Out of which:														
Cereals and legumes	178.4	188.7	193.1	198.1	155.2	130.2	121.2	30.8	31.8	31.3	30.7	19.8	26.1	16.9
Potatoes	30.7	31.6	27.8	28.9	25.3	22.1	20.5	214.3	232.2	217.8	209.8	214.9	187.3	199.2
Vegetables	25.4	26.4	28.4	30.2	28.3	21.7	20.6	333.7	350.5	334	301.8	286.3	258.6	265
Melons	5.4	5.8	6.8	7.3	6.8	4.6	4.3	388.5	421.4	423.4	325.1	316.8	276.3	300.6
Fruits and berries	40.2	40.1	40.3	40.5	42.3	43	43.6	95.0	80.8	103	66.1	93.5	87.7	76.7
Grapes	17.5	17.2	17.3	17.1	15.8	16.1	16.3	149.8	157.7	188.2	110	141.4	120.1	148

Table 4: Gross yield of basic agricultural crops and perennial plantations, 2013-2019

	Gross harvest (thousand tons)						
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Cereals and legumes	549	591	602	604	303	338	199
Potatoes	661	73	608	606	547	415	404
Vegetables	876	955	1,008	969	861	628	622
Melons	208	246	287	236	216	127	128
Fruits and berries	338	291	377	243	362	343	290
Grapes	241	261	309	179	210	180	217

[23] Ibid

Livestock production

Livestock production is mostly focused on cattle breeding, sheep breeding, pig breeding and poultry.

Cattle breeding is the leading branch of the livestock sector of the country. Around 95% of the milk is produced in the country, almost 63-64% of the meat is obtained from cattle breeding (Table 5). According to the final results of the Comprehensive Agriculture Census, there are 181,602 agricultural holdings in the country involved in livestock production of which around 111 thousand holdings involved in cattle breeding. 29.9% of the cattle breeding holdings has 5-9 heads of cattle, 27.6% - 3-4 heads and 24.9% - 1-2 heads[24]. According the SCRA, the greatest number of cattle is concentrated in Gegharkunik, Shirak, Lori and Aragatsotn regions (Figure 4).

The main breed of the cattle in the country is Brown Caucasian. According to the MoE[25], this breed accounts 93% of the total number of cattle. This breed was created and selected for suitable adaptation to local conditions taking into account the mountainous area of the country and are kept for both milk and meat production. However, the structural changes that followed the independence of Armenia in the 1990s, had strong negative effects on the support and development of this breed. Large-scale pedigree breeding works were stopped in the privatized cattle herds. Farmers started to use bulls of unknown origin leading to lower-grade animals and production. Currently, to maintain high quality animals, farmers usually resort to importing high quality breeds and/or their semen to do artificial insemination.

Thanks to the work carried out in recent years on artificial insemination, as well as government support programs on development of cattle breeding, the breed of animals, as well as the breed composition in some farms have significantly improved. Besides Brown Caucasian, there are also Holstein, Brown Swiss, Simmental breeds in the farms, to a smaller extent. In different regions, different feeding and management system are available based on the availability of feed, pastures, fodder crops, etc. In Ararat valley, in those communities where area of pastures is very limited, the stall-based farming of cattle is mostly used, whereas in the pre-mountainous and mountainous areas, the pasture-stall farming is used.

Sheep breeding is also one of the traditional branches of livestock production. It is developed in the sub-mountainous and mountainous areas of Armenia with extensive pastures as well as in Ararat valley. According to the SCRA, the most concentrated number of sheep is registered in Armavir, Syunik, Gegharkunik, Aragatsotn and Ararat marzes. Farmers in Armavir and Ararat regions in the summer use remote pastures in mountainous regions, which are mostly not used by local farmers.

Pig breeding is one of the important branches of the livestock production sector in the country. It is well developed in Kotayk, Armavir and Ararat Marzes of the Republic of Armenia, where the largest population of pigs is concentrated. Armenia annually produces 16-17 thousand tons of pork (slaughter weight) (Table 5).

Armenia has well developed poultry breeding which is the most mechanized branch of the livestock sector in Armenia. According the MoE, currently there are more than 10 poultry farms of medium and large size in the country, which are engaged in production of poultry meat and eggs. Armenia annually produces about 700 million eggs and 7-8 thousand tons of poultry (Table 5).[26]

[24] GAC, SCRA, 2016. Link: https://armstatbank.am/pxweb/hy/ArmStatBank/
[25] Ministry of Economy, website https://www.mineconomy.am/page/1329
[26] Food Security and Poverty, January-December 2020, SCRA, 2021

Figure 4: Regional distribution of cattle and sheep, %, 01.01.2020

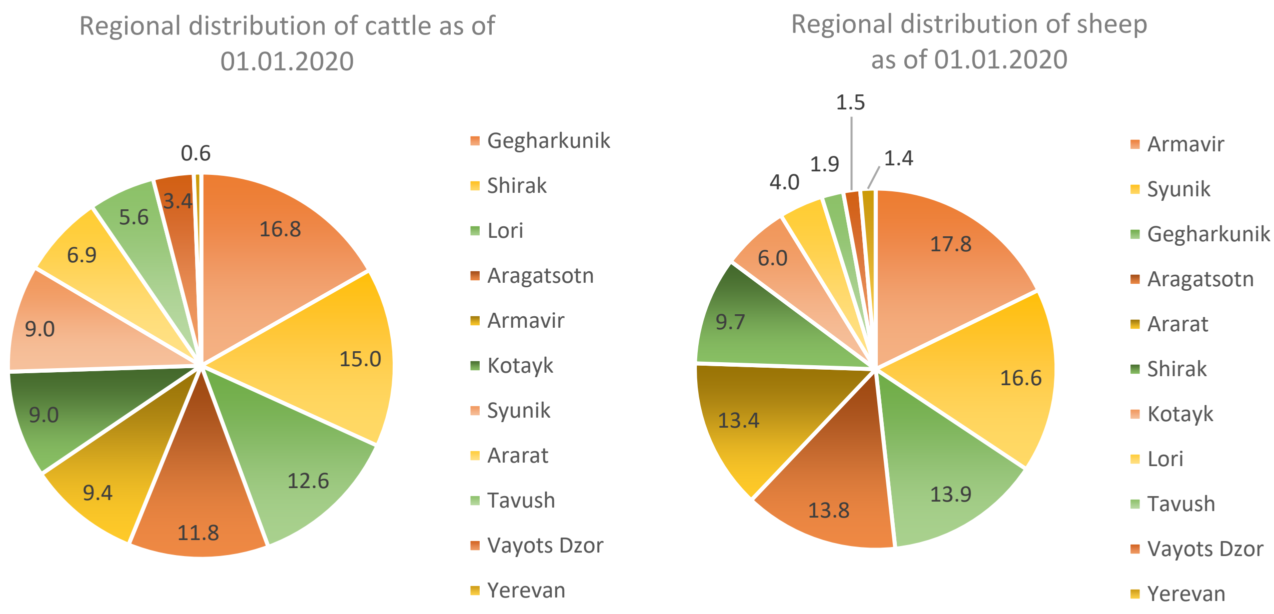


Table 5. Production volumes of basic livestock products, 2010-2019

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Beef	thousand tons	48	48.2	47.6	53.6	59	63.6	68.1	70.8	68.8	68.1
Pork	thousand tons	7.9	9.4	9.5	12.6	16.2	17.5	18	16.6	16.3	16.1
Mutton and goat	thousand tons	8.2	8.4	8.5	9	9.1	9.8	10.3	11	10.8	10.7
Poultry	thousand tons	5.4	5.7	8.3	8.2	8.4	9.5	9.7	10.6	12.3	12.4
Milk	thousand tons	601	602	618	657	700	729	754	758	698	668
Eggs	million pieces	702	634	658	615	642	660	695	683	727	721
Wool	thousand tons	1.19	1.23	1.28	1.43	1.48	1.57	1.64	1.39	1.03	0.98
Fish	thousand tons	6.5	8.2	11.2	15.6	18.6	23.3	20.1	17.1	17.2	18.3

Export

The agricultural sector has significant potential for export, which has led to increased investments in the sector. Exports of agri-food sector have increased in recent years. In 2019, the indicator has almost doubled as compared to 2015 (Figure 5).

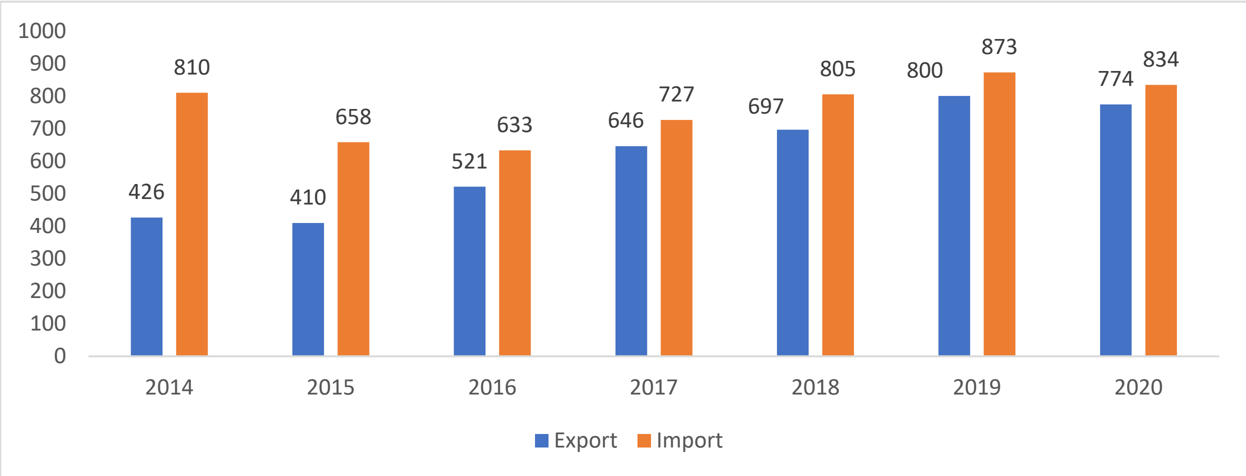
Nevertheless, the export volumes of the sector are still low. In particular, the share of ready-made food exports in the total volume of agriculture exports in 2018 and 2019 was 28.9% and 30.2%, respectively. A significant percentage of this indicator is tobacco exports, which is mostly based on imported raw materials. Without the latter, the corresponding figures would be 17.8% (2018) and 19.2% (2019). [27] The main exported

[27] Exports and imports of RA by indicators, foreign trade and years
Link: https://armstatbank.am/pxweb/hy/ArmStatBank/ArmStatBank__5%20Foreign%20trade/FT-1-2019.px/?rxid=604fed6c-28a4-4904-8d31-0d56dea555e0

products of the sector are beverages, tobacco, fruits and vegetables. Those exports in 2019 comprised 293, 291 and 96 million USD, correspondingly. The main imported goods are tobacco, cereals, meat/meat products, animal feed, various fats, oils, alcoholic beverages, confectionery and sugar.

It should be noted that due to the Covid-19 pandemic during 2020, the exports from the sector have decreased compared to 2019. Interestingly, the decrease is due to fall in exports of ready-made food products (83.0 million USD or 12.8% more less exports). On the other side, exports of livestock, products of animal origin and products of plant origin increased by 27.1 million USD (52.7%) and 29.2 million USD (27.3%), respectively[28].

Figure 5: Import and export of agricultural products in 2014-2020 (for 01-24 HS codes), million US dollars



2.2.3. Structure of farms and use of main resources

The small-scale farms, which are characteristic for the country, restrain the development of agriculture, including modernization and commercialization, limiting its ability to invest in modern agricultural technologies and reducing the incentives to engage in market activities. It is also a serious obstacle for the efficient organization and management of agricultural production, the use of crop rotations in those areas and the preservation of soil fertility.

According to the results of the General Agricultural Census (GAC) (2014), there are 361,064 farms in Armenia (farms engaged in the production, processing, storage, transportation, sale, etc.) out of which 99.87% belong to agricultural holdings without legal status, and 0.13% belong to agricultural holdings with legal status. 96% of those farms (346,276 farms) have agricultural lands. 317,799 farms (88% of the total number of farms) are engaged in active agricultural activity. The holdings without legal status produce about 97% of the gross agricultural product. Each has on average 1.48 ha of agricultural lands, and the holdings with legal status - 62.57 ha. Overall, the average agricultural land per holding is 1.54 ha.

The lands belonging to the farms, in their turn, are quite fragmented and more than 40% of the farms have agricultural lands consisting of 3 or more land plots. About 41.7% of farms have less than 0.5 hectare, and 60% - less than 1 hectare of agricultural land. Only 1.2% of the farms have areas of 10 ha and more, the latter own more than 15% of the agricultural lands (Table 6).

[28] Imports and Exports, Socio-Economic Situation of RA, January, 2019-December, 2020
Link: https://www.armstat.am/file/article/sv_12_20a_411.pdf

Table 6: Number of farms by size of agricultural land (including farms with adjacent land) [29]

Total agricultural holdings	*based on land size (ha)*												
	Up to 1	0.1 - 0.19	0.2 - 0.49	0.5 - 0.99	1 - 1.99	2 - 2.99	3 - 4.99	5-9.99	10-19.99	20-49.99	50 -99	100-199	200 and more
1	2	3	4	5	6	7	8	9	10	11	12	13	14
346,217	**78,452**	**24,473**	**41,411**	**62,002**	**69,908**	**31,240**	**22,318**	**12,394**	**2,901**	**868**	**153**	**58**	**38**

As a result, the country's small-scale farms are often perceived to act as barrier for the agricultural development, modernization and commercialization. In particular, they limit the ability to invest in modern farming technologies and reducing market incentives. This is also a serious obstacle for the efficient organization and management of agricultural production, including the use of crop rotations, and preservation of soil fertility, thus contributing to the mitigation of GHGs.

The main agricultural resources

Effective management of agricultural resources is crucial for the organization of efficient agricultural production. However, the use of these resources in Armenia, such as land, water and biological resources in general, is far from being effective. As a result, the cost of production increases, quality and competitiveness decrease and these lead to a decrease in the efficiency of agricultural products. The inefficient use of resources makes agriculture more vulnerable to the risks of disasters and climate change.

Land resources

Agriculture, as a strategically important sector of the country's economy, is still at a low level of development from the perspective of utilizing its production potential and land use. One of the main reasons for this is the farm structures including small size of farms, which hinders the efficient organization of agricultural production.

Armenia is not rich in land resources and those resources are limited. According to the RA Government 2019 report on “The availability and distribution of the RA land fund”, agricultural land composes 68.7% of the country's territory, the lands of the settlements - 5.1%, the forest lands - 11.2%, as well as the lands of specially protected areas - 11.3%. Citizens own 18.1% of the land, 1.2% of the lands are under the management of legal entities, whereas 34.5% and 46.2% of the lands represent community/state property[30].

According to the Government of Armenia, approximately 2,044 thousand ha or 68.7% of the total lands of Armenia are agricultural lands. The area of arable lands from agricultural lands makes up 21.8% (445 thousand ha), and permanent crops - 1.8% or (36 thousand ha). The main part is pastures and other lands, respectively 51.4% and 19.1%. Only 7.6% of agricultural land, 26.6% of arable land and 97.5% of permanent crops are irrigated (Table 7).

[29] GAC, SCRA, 2016. Link: https://armstatbank.am/pxweb/hy/ArmStatBank/

[30] RA Government decree N1379-N on the availability and distribution of the RA land fund (land balance), RA Government, October 03, 2019. Link: http://www.irtek.am/views/act.aspx?aid=101871

Table 7: Agricultural land balance of the RA as of October 3, 2019[31]

Description	Total land	of which irrigated
	thousand hectares	
Area of the Republic of Armenia	**2,974.3**	**208.7**
of which agricultural land	2,044.2	155.2
of which:		
arable lands	444.8	118.2
permanent crops	36.4	35.5
grasslands	121.1	1.5
pastures	1,051.1	-
other lands	390.8	-

Since the privatization of land in post-independence Armenia, there have been continuous changes in the level of land use. Studies of land balances indicate that in 2019 as compared to 1990, arable lands reduced by 9.6% or 47 thousand ha, fruit plantations - by 56.5% or 47 thousand ha. During the period from 2006 to 2019, the total area of agricultural lands reduced by 4% (from 2,130 thousand ha in 2006 to 2,044 thousand ha in 2019). This has mainly been due to the reduction of arable land, grasslands, pastures and other land areas.

During the mentioned period, only the area of perennial plantations increased by 9.1 thousand ha. Due to the deterioration of the socio-economic situation after the land privatization, the lands with perennial plantations significantly reduced from 45.4 thousand ha in 1991 to 21.6 thousand ha in 1998. However, along with the increase in the profitability of the sector, the aforementioned plantations started to expand, the economic entities established new orchards and vineyards. In 2019, the area of perennial crops increased by 1.1 thousand ha in comparison to 2018. This has been due to the investments in the sector, as well as government support programs. Intensive orchards have a significant share in the newly planted gardens, which can provide sustainable prospects for the development of the sector.

The state of use of agricultural lands in the Republic of Armenia

One of the most important indicators for determining the state of use of agricultural lands is the level of targeted use of arable lands. According to the 2014 GAC, on average, 33% of arable land of holdings without legal status and 38% of holdings with the legal status are abandoned. These figures do not include the areas of unused orchards and vineyards, which if taken into account, will increase the discussed figures[32].

According to "The Strategy" in 2018, out of 446 thousand ha of arable land in Armenia only 243 thousand ha or 55% were used in accordance with their purpose.

Land abandonment has multiple causes and is often the result of a complex multi-dimensional setting with interlinked social, economic and environmental factors. A number of negatively affecting trends, such as the structure of farms, which is expressed in small farms, excessive land fragmentation, aging rural population, emigration, severe dependence of agricultural production on the availability of facilities for irrigation,

[31] Ibid
[32] GAC, SCRA 2016. Link: https://armstatbank.am/pxweb/hy/ArmStatBank/

agricultural value chain and the growing problem of land degradation contribute to the problem in combination[33].

"The Strategy" envisages to reduce the volume of unused arable land by 25% by 2030 as a target indicator. In 2020, the Government of the RA has approved the decision "On approving the concept and action plan on increasing effectiveness on utilization of agricultural lands"[34]. It envisages a number of measures to develop and implement effective structures to promote the inclusion of agricultural lands in agricultural circulation, which will increase the level of efficiency of agricultural land use and agricultural production.

Abandoned land has huge unutilized potential for local economic growth by strengthening local food production and by using this potential for local economic growth in rural areas (both production, processing, sale on local markets, etc.). Bringing abandoned land back into production will positively contribute to achieving several SDG targets including the ambitious SDG target 2.3 on doubling the agricultural productivity and income of small-scale food producers.

Currently, FAO supports the RA Ministry of Economy in the development of a regulatory framework and introduction of a set of land management instruments (e.g., land banking, facilitation of lease and land consolidation) to address abandonment of agricultural land and improve farm structures by reducing land fragmentation and facilitating farm enlargement on a voluntary basis. Furthermore, FAO is supporting the development of a web-based IT platform to be used for the facilitation of lease instrument, subsequently, in a countrywide approach.

Land Degradation in Armenia

As a result of land privatization, about 340,000 small farms, scattered and fragmented lands contributed to the violation of agro-technical rules of cultivation, irrigation regimes, irrigation norms, crop rotation, which lead to land degradation, especially erosion and decrease of organic carbon in the soil.

Armenia's agricultural land resources are particularly vulnerable to desertification, which is in part due to geographical, climatic, inefficient and non-targeted management conditions. In the absence of a management system for these resources, the processes of desertification and related land degradation currently about 80% of land plots in Armenia are characterized by various levels of land degradation, and about 43% by desertification phenomena.

Soil degradation in the Republic of Armenia is mainly due to erosion, compaction (hardening), rockiness, rising groundwater, salinization and alkalinization, man-made pollution, violation of irrigation norms, landslides, floods, as well as declining soil fertility. Soil erosion, especially water erosion, in all natural areas of Armenia is progressive. More than half of the Republic's land is more or less subject to erosion. About 50% of the entire zone soils (2,700 thousand ha) are eroded, and the rest have different degrees of erosion (weak to strong). The degree of erosion may reach to up to 75%. According to estimates, there are currently 1,498,400 ha of eroded area in Armenia, of which 1,476,400 ha are subject to water erosion and 22,000 ha are subject to wind erosion[35].

[33] Policy Note on land abandonment and recommendations for policy advice on introduction of a land consolidation instrument in Armenia, FAO, 2018.

[34] RA Government decree 68 L On approving the concept and action plan on increasing effectiveness on utilization of agricultural lands, RA Government, January 23, 2020. Link: http://www.irtek.am/views/act.aspx?aid=103616

[35] "The Impact of Climate Change on Land Degradation and Fertility in Armenia", FAO, 2017. Link: http://dcf.am/hy/publications

The negative impact of erosion extends not only to agricultural lands, reducing soil fertility and crop yields, but also to the landscape. This contributes to the flooding of rivers and reservoirs, deteriorating water quality (due to ingested nutrients, other chemicals), reducing agricultural incomes and adversely affecting social conditions.

Among the anthropogenic factors causing soil erosion, agricultural misconduct (violation of agricultural machinery, driving along the slope, lack of crop rotation, inefficient use of irrigation water, overgrazing of pastures, deforestation, etc.) have a special place.

The intensity of erosion and the consequent decrease in soil fertility inevitably increase the production costs of agricultural crops, as additional financial resources are needed to ensure an adequate level of fertility, in particular to increase the use of mineral fertilizers, which contribute to GHG emissions.

Water usage

The problem of irrigation is not so much due to the lack of water resources but rather due to the use of water with low efficiency, large losses of water resources and lack of proper distribution mechanisms aimed at more efficient and modern irrigation systems.

Armenia's agricultural sector is highly dependent on irrigation and irrigation infrastructure significantly contributes to agricultural production. Irrigation is considered to be one of the most important measures to increase soil fertility and productivity in regions with naturally insufficient and unstable moistness. In terms of the amount of water per capita (2,300-2,500 cubic meters) and the total area of agricultural land, the RA is considered a water-scarce country. In some parts of the country, there is a significant mismatch between the availability and demand of water resources.

As of October 2019, the total irrigated area in Armenia was about 209 thousand ha, of which irrigated agricultural lands make 155 thousand ha or 74.4%. Another 53 thousand ha or 25.4% of the backyard lands are irrigated.

However, according to some estimates, on average, only 110,000-130,000 ha of irrigated land is actually being irrigated annually.[36] The irrigated agricultural lands have sharply decreased from 1990, when the total area of irrigated agricultural lands in the country were 275-280 thousand ha. The main irrigation infrastructure was originally designed and built during the Soviet era to supply the specified area with 2.5 billion cubic meters of irrigation water, annually.

Existing problems in the field

One of the problems of the sector is not only the availability of irrigation systems, but also its low level of effective management. The limited areas of irrigated agricultural lands, and in some cases the poor condition of the existing irrigation infrastructure of those lands, the loss of irrigation water are the main obstacles for obtaining high yields. Currently, the poor condition of economic linkages, insufficiently organized irrigation

[36] Sustainable, Inclusive Agriculture Sector Growth in Armenia: Lessons from Recent Experience of Growth and Contraction, World Bank 2017
Link: http://documents1.worldbank.org/curated/en/701491522220670956/pdf/124666-WP-PUBLIC-FINAL-Armenia-SCD-publication-of-technical-background-papers-on-agriculture-final-040518.pdf

works, inefficient irrigation water management, including unscientific application of irrigation regimes and irrigation norms, surface irrigation, which is the main method of irrigation, result in at least 45-50% loss of irrigation water[37]. The technique of mainly surface irrigation has a number of disadvantages. In particular, severe shortage of water resources has a significant negative impact on sustainable water supply to agricultural crops; fertilizers used for surface irrigation are not evenly distributed in the field, irrigation water is often washed away and nutrients move to the deeper layers of the soil. The same is true regarding certain pesticides.

In the drier areas of the foothills, where most of the land is not irrigated due to the unavailability of irrigation water or the lack of an irrigation system, there is a sharp decline in yields in some years, which is more common in recent years. This problem will deepen in the future due to climate change and the increase in the number of dry years.

The problem is sometimes not so much due to the lack of water resources but rather due to the lack of proper distribution systems for the use of more efficient, modern irrigation systems.

Current state of crop rotation and fertilizer application

In aftermath of the land privatization, a large number of farms were established, characterized with small, fragmented pieces of land, inefficient structure and management. This resulted in violations of the application of scientifically grounded crop rotation and fertilization systems, mineralization of organic substances as well as land degradation. As consequence, indicators of soil fertility, organic carbon and humus reserves have significantly decreased during the recent years.

Fertilizers, whether organic or mineral, are used to improve soil nutrition: plant nutrition and its yield. In this regard, fertilizers are an important component of food security. Fertilizers increase agricultural productivity, stimulate the reduction of CO_2 as a result of photosynthesis by plants. However, the production, transportation, and use of mineral fertilizers directly and indirectly contribute to the emission of GHG, particularly carbon dioxide (CO_2) and nitrous oxide (N_2O). In particular, the use of nitrogen fertilizers has a significant effect on methane (CH_4) and nitrous oxide (N_2O) emissions.

In Armenia, where the soils are significantly degraded, the share of eroded soils is large - they are not rich in appropriate macro and micro elements. The use of fertilizers is a necessary precondition for increasing yields and maintaining the soil fertility. Not enough organic fertilizers are used in the country due to the small size of livestock, as well as the use of significant amounts of manure as fuel. Given the above, mineral fertilizer supplementation is imperative to avoid soil degradation.

During the Soviet Union period, agriculture sector in Armenia was at relatively intensive level, large amount of fertilizers were used. The volume of application of nitrogen-phosphate fertilizers in the Republic reached 150-170 thousand tons per year (Table 8).

[37] Agriculture in Armenia snapshot, Avenue Consulting Group, 2014.
Link: https://avenueconsulting.am/agruculture-in-armenia-snapshot/

Table 8: Volumes of fertilizer used in Armenia in 1985-1991, in thousand tons[38]

	1985	1986	1987	1988	1989	1990	1991
Nitrogen fertilizers only	166.3	171.8	144.1	124	107.4	70.8	58.7
of which:							
nitrogen nitrate	125.6	132.9	103.9	91.6	98.8	62.4	35.9
carbamide	40.7	38.9	40.2	32.4	8.6	8.4	22.8
Phosphorus fertilizer (superphosphate)	155.3	168.2	149.4	115.8	84.7	32.0	26.1
Potassium fertilizer	28.8	29.6	24.9	21.4	11.1	16.9	1.9

After the collapse of the Soviet Union, the limited consumer market forced land users to cut crops, such as the formerly lucrative orchards and vineyards, replacing them with more affordable, relatively less risky crops such as wheat, potatoes, and vegetables and fodder crops such as alfalfa and sainfoin. As a result of violations of agricultural rules, non-application of scientifically based crop rotations, incomplete and in some cases unilateral fertilization of lands and land degradation and desertification there has been significant decline in crop yields.

After the privatization of the land in Armenia, the import of fertilizers sharply decreased. In the 2000s, the use of mineral fertilizers was reduced by more than 10 times, and the use of organic fertilizers was reduced by almost 18 times. However, in the last decade, the import volumes of mineral fertilizers have significantly increased; in recent years, about 60-80 thousand tons of nitrogen fertilizers have been used, annually. In 2016, 146 thousand tons of nitrogen fertilizer was imported, which is close to the volume of use in the Soviet Union period. In contrast to nitrogen fertilizers, the volume of imports and uses of phosphorus-potassium fertilizers is quite small and on average, imports over the last ten years have amounted to 600 tons for each type, respectively (Table 9).

Table 9: Volumes of import of fertilizers of mineral and plant with animal origin in RA expressed in physical weight, tons 1995-2020 [39] [40]

Year	Nitrogen	Phosphate	Potassium	Complex	Fertilizer of plant and animal origin
1995	18,678	-	-	480	-
1996	9,616	-	-	-	-
1997	35,049	-	-	22	-
1998	38,266	-	-	-	-
1999	38,494	2	12	3	-
2000	31,175		3	31	2
2001	27,555	1	6	147	5
2002	45,156	0	2	41	0
2003	39,392	-	-	58	-
2004	48,698	-	9	2,359	1
2005	46,208	-	16	229	-
2006	57,921	-	1	472	0
2007	26,808	-	12	374	33

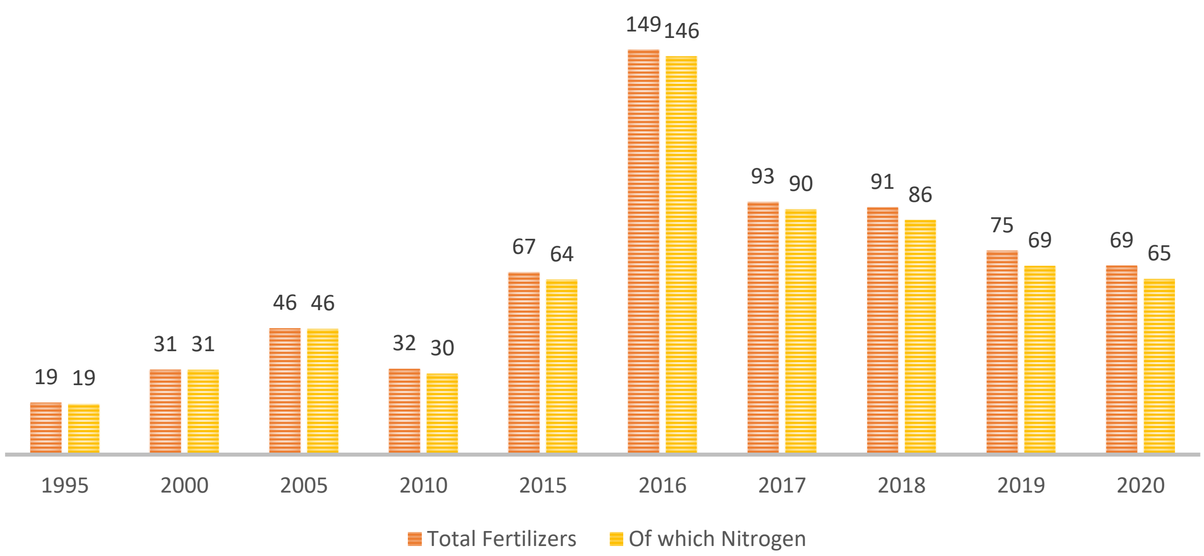
[38] RA Government decree N 801 on National Environmental Action Plan, RA Government, December 14, 1998 Link: https://www.irtek.am/views/act.aspx?aid=5898

[39] Foreign trade database according to the 4-digit classification of the product name list, SCRA, 1995-2015 Link: https://www.armstat.am/am/?nid=148

Year	Nitrogen	Phosphate	Potassium	Complex	Fertilizer of plant and animal origin
2008	24,331	23	36	212	52
2009	39,542	0	5	529	59
2010	29,776	34	4	1,699	5
2011	35,947	415	4	466	900
2012	57,447	66	514	1,644	1,502
2013	58,599	559	39	1,416	2,230
2014	48,636	2,777	1,700	1,293	1,481
2015	64,342	1,676	82	965	1,431
2016	146,292	324	915	1,246	84
2017	90,106	23	210	2,567	114
2018	86,151	3	927	3,833	170
2019	69,340	137	764	4,749	200
2020	71,243	14	823	4,947	198

The program "State support to land users to purchase fertilizers at affordable prices" implemented by the Government of the RA has contributed to the increase of fertilizer import volumes during 2007-2018. Nitrogen fertilizer import and use volumes make up more than 95% of total imported fertilizers. This means that in Armenia the use of nitrogen fertilizers is entrenched (Figure 6).

Figure 6: Fertilizer import volumes and the share of nitrogen fertilizers in those volumes, thousand ton



The use of fertilizers, in particular, nitrogen fertilizers, by the farms of the country is carried out without control, naturally, irregularly, violating the norms of use of fertilizers per unit area, terms of use, and methods of their application. Furthermore, irregular use of fertilizers without control on nutrient release patterns causes leaching or escaping of nitrogen in gaseous form into atmosphere.

No scientifically based fertilization system is used. Sometimes, farms use 4-5 times more nitrogen fertilizers than the established norms, especially those farms engaged in growing potatoes and some vegetables. Unilateral nitrogen fertilization, in turn, contributes to the increase in the amount of nitrates in the crop, inefficient use of nitrogen fertilizer by the plant. As a result, most of the fertilizers are not used by the plant and are either washed away into the deeper layers of the soil or the nitrogen oxide emissions from the soil rise significantly. As a result, environmental problems arise in terms of soil, water pollution, increasing nitrogen oxide emissions, deviations from the norms of nitrates in food.

Similar phenomenon occurs due to the storage and irregular use of organic fertilizers - manure. The lack of manure and manure storage facilities greatly contributes to it. It is found that in case of violation of fertilization technology, the loss of organic fertilizers is 10-20%. The loss of organic matter from barns, livestock farms is often 20-40% of the total volume.

The use of scientifically based crop rotation has a unique role in increasing soil fertility, preserving and ensuring high yields of crops, especially in the current conditions, and improving soil organic carbon content.

The low level of land use in the current land relations primarily has a quite negative impact on soil fertility. Violation of soil cultivation technology, cultivation of monoculture agriculture, non-use of crop rotations, unbalanced use of mineral fertilizers, limited use of organic fertilizers, anti-erosion works, neglect of soil moisture accumulation are the main reasons of the decline of normal soil fertility and low crop yields as well as the content of organic carbon.

The fragmented lands and the small size of the farms have now created difficulties for the use of crop rotation, while without it is impossible to solve the problems of maintaining the fertility of the lands and obtaining high yields. For many years, farms have been cultivating the same crops on the same land: wheat, barley, potatoes, vegetables, etc. This has led to soil erosion, declining fertility, and intensification of windfall. Favorable conditions are created for the development of weeds, diseases, pests, which in turn leads to an increase in the volume of pesticides used.

The current state of plant protection and pesticide use

Plant protection is one of the critical areas of agriculture, without which it is difficult to get high-quality crop. The diversity of climatic conditions of the Republic, the widespread zoning, the wide range of crop varieties contribute to the formation of different populations of pests. This cause significant damage to agriculture every year. In this regard, the role of plant protection is strengthened.

Plant protection products or pesticides (herbicides, fungicides, insecticides, etc.) are used to control diseases of agricultural crops, pests and weeds, which can have a negative impact on the environment, including soil pollution and other environmental factors. Pesticides in soil, water and air can be stable and mobile and can affect nature, wildlife and people through the food chain.

Prior to land privatization, storage, distribution and use of pesticides and fertilizers were centralized and properly accounted for. The Soviet farms had a chief agronomist, and, if necessary, a plant protection agronomist, who was responsible for plant pests and disease control, preservation and application of pesticides. After the privatization of lands (1991), the state plant protection system in Armenia almost ceased to exist due to insufficient funding; the situation in the field of plant protection deteriorated sharply. Plant protection consulting was provided by the State Advisory Service, which has been in place since 1994, along with other specialists in the field. However, this has been of small scale and has largely failed to serve a large number of farms.

Due to lack of professional experience and skills, land users have faced serious difficulties in organizing measures to control crop pest and diseases. In this regard, for years, as a result of the lack of systematic and follow-up measures, a number of diseases and pests have become more and more widespread. Consequently, the farms have had large crop losses.

Nowadays, households often choose wrong methods and means of plant protection. The terms of the protective actions are violated, the dosages of pesticides used and necessary efficiency level is not reached. Often, certain farms do not carry out control procedures due to lack of resources, knowledge and equipment, which complicates the overall control environment.

Farmers mainly independently try to diagnose the diseases and pests, determine the methods of controlling them, the choice of pesticides, the doses, dates, frequency, etc. As a result of uncoordinated and unprofessional activities, the fight against certain diseases and pests has become quite difficult.

At present, plant protection in the country is mostly carried out with chemical pesticides. This does not often demonstrate the desired effectiveness, moreover, harm human health and pollute the environment. Pesticide doses, maximum allowable repetitions, waiting times and safety rules are generally not observed. Businesses have to use high doses of pesticides and perform frequent treatments. Integrated control activities are not carried out in a systematic way. In particular, no biological measures are applied; and the level of mechanical, agro-technical application of other methods of control is low due to the lack of necessary knowledge and resources.

Often, due to the use of obsolete and defective equipment and sprayers, the quality and efficiency of spraying is severely reduced. It is not possible to maintain the prescribed doses of pesticides and the cost of working fluid.

Prior to land privatization, pesticide use was quite high and reached up to 6,000-7,000 tons per year. This, together with the large amounts of mineral fertilizers used, caused serious environmental tensions (Table 10).

Table 10: Volumes of pesticide use in Armenia in 1988-1991[41]

Pesticide groups	***Volumes of use, tons by dates***			
	1988	**1989**	**1990**	**1991**
Herbicides	183	247	183	113
Insecticides	535	779	510	536
Fungicides	5,523	6,145	4,590	2,838
Zoocides	40	30	37	28
Disinfectants	14	17	13	14
Total:	**6,295**	**7,218**	**5,333**	**3,529**

After the privatization of the land, the import volumes of these pesticides decreased; and until 2000, only up to 200-300 tons were imported annually. Currently, imports have risen sharply and reached 2,444 tons in 2018 (Table 11).

Table 11: Volumes of import and export of RA pesticides, tons [42]

Year	**Export**	**Import**
1997	0	118
1998	0	126
1999	18	296
2000	3.6	217

[41] RA Government decree N801 on National Environmental Action Plan, RA Government, December 14, 1998
Link: https://www.irtek.am/views/act.aspx?aid=5898

[42] Foreign trade database according to the 4-digit classification of the product name list, SCRA, 1997-2015
Link: https://www.armstat.am/am/?nid=148

Year	Export	Import
2001	1.1	248
2002	0.6	209
2003	1.5	278
2004	2.1	457
2005	19	540
2006	1.6	538
2007	27	585
2008	2	615
2009	1.2	527
2010	0	736
2011	0	940
2012	8.9	1,143
2013	1.3	927
2014	0	1,361
2015	2.7	1,170
2016	2.1	1,375
2017	48	1,212
2018	12.8	2,445
2019	33.7	1,816
2020	245,3	2,551

Production of plant protection products is not organized in the RA, and some quantities of pesticides imported in recent years are exported to third countries.

In Armenia, the registration of pesticide use (according to the volumes of pesticide use, chemical composition, species, according to the volumes of the active ingredients, crops, quantities used per unit area) is not carried out. The absence of these data does not provide a complete picture of the environmental problems caused by the use of pesticides.

Food waste and loss

The issue of food waste and lose in Armenia is relatively poorly investigated. A study conducted in 2014 demonstrated relatively high levels of food waste and loss in the country. The highest losses are found in fish and eggs, approximately 20% each, mainly in agricultural production stage due to animal mortality. The highest losses in crop production are demonstrated in cereals - 19%, roots and tubers (mainly potato) - 15%, in post-harvest handling and storage stages, due to overall poor condition of irrigation systems, handling and storage infrastructures, etc. (Food lose and waste need to be considered under the Waste sector, and this is not further discussed in the scope of the current Study).[43]

2.3. Climate change and the negative impact of natural disasters on agriculture

Mitigation activities are largely dependent on the preconditions of the trends observed in the natural landscape and agro ecological preconditions which shape the development of the sector. This chapter examines climatic conditions for air, water, soil, etc., which have been observed in Armenia during the recent period and may also determine the success of the mitigation activities.

[43] "Food losses and wastes in Armenian agri-food chains", V. Urutyan and A. Yeritsyan, 2014.

Preconditions

Natural landscapes in the territory of the Republic of Armenia have undergone significant changes during the last few decades, mainly due to anthropogenic intervention, as well as global climate change. This has led to severe deterioration of water regimes, microclimatic conditions, soil fertility and increased erosion[44].

Agriculture is affected by climate change, but it is also a driver of climate change itself, through the release of greenhouse gases (GHGs). The agriculture sector can also significantly contribute to reducing greenhouse gas (GHG) emissions, and therefore future actions should focus on those that have multiple benefits for adaptation, mitigation, and biodiversity. Many of the adaptive measures also contribute to the climate change mitigation and some climate change mitigation measures contribute to the climate change adaptation. In addition to its potential to reduce GHG emissions, agriculture is the only sector that has the capacity to remove GHGs safely and cost-effectively from the atmosphere without reducing productivity. Agriculture has the potential to benefit from synergies between climate change adaptation and mitigation within the right enabling conditions[45].

Climate change mitigation and adaptation and actions are important for agriculture, as it has important socio-economic implications for society and food security. The Paris Agreement underlines the fact that adaptation measures need to be implemented in synergy with mitigation actions, and it is emphasized that food production systems need to be less vulnerable to the adverse impacts of climate change.[46]

The implementation of mitigation measures at farm level, preserving farmers' competitiveness, has proved to be feasible and an effective strategy to fight climate change. Mitigation measures at farm level are cross-cutting actions with parallel benefits such as improving competitiveness, providing a better knowledge of the farms, tackling other environmental challenges, etc. [47]

Mitigation measures can be planned to help reduce, and not inadvertently exacerbate, disaster risks. For example, conservation agriculture has been proven to reduce farming systems' greenhouse gas emissions and enhance their role as carbon sinks. Furthermore, conservation agriculture practices can also contribute to making agricultural systems more resilient to climate change and reducing farmers' vulnerability to drought and soil degradation through the intensification of sustainable production. Agroforestry is increasingly recognized as a land management system that can serve as a response option for both climate change adaptation and mitigation, while addressing many of the challenges that smallholder farmers are facing. Agroforestry can generate multiple livelihood and environmental benefits, as it can help to mitigate climate change and help farmers to adapt to extreme and variable weather, drought, etc.[48]. Benefits of agroforestry to smallholder farmers include increased farm productivity and reduction of external inputs such as conventional fertilizers and chemicals for pest management, leading to increased income.

Expected climate change, such as rising temperatures, declining water availability, and increasing the frequency and intensity of other emergencies, will exacerbate these problems and pose a serious threat to the future of sustainable agricultural production and the republic's food security. This may also pose a threat to the mitigation activities suggested as a result of this study.

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[44] The Impact of Climate Change on Land Degradation and Fertility in Armenia, United Nations Food and Agriculture Organization (FAO), 2017. Link: http://dcf.am/hy/publications

[45] Mitigation of Climate Change in Agriculture (MICCA) Programme. Link: http://www.fao.org/in-action/micca

[46] Adoption of the Paris Agreement, United Nations Framework Convention on Climate Change, UNFCCC, 2015, Link: https://unfccc.int/resource/docs/2015/ cop21/eng/l09r01.pdf

[47] Measures at farm level to reduce greenhouse gas emissions from EU agriculture, European parliament 2014, Link: https://op.europa.eu/en/publication-detail/-/publication/84e80564-6445-475a-be9c-4b6b2e9e31b2

[48] Climate Change and Land, IPPC 2020, https://www.ipcc.ch/srccl/

Armenia is in a high-risk zone of natural hazards and subject to their high influence. Armenia can be characterized with about 110 natural hazards known in the world, of which 10 most common types of disasters appear more often and their impact is much more significant.[49]

Geographical location of Armenia, emphasized vertical zoning of the area, fragmentation of mountainous terrain, low and insufficient soil moisture[50], natural hazards have a negative impact on agriculture. The high-risk rate is due to climatic factors, biological hazards and the specifics of the sector. This is conditioned by the small volume of irrigated agricultural areas, poor condition of irrigation systems, low level of soil moisture, etc.

Droughts, hailstorms, early spring frosts, the frequency and intensity of which have been increasing in recent decades in the context of climate change, are one of the most dangerous hydro-meteorological hazards for agriculture.[51] The annual damage to agriculture from drought, hail, spring frosts and floods in recent years is estimated at about 15-30 billion AMD[52]. Moreover, most of the damage is due to hail.

According to incomplete data provided by the RA Ministry of Emergency Situations and RA Ministry of Economy, the average annual loss of agricultural products due to hazardous hydrometeorological hazards amounted to more than 423.5 billion AMD during the period 1995-2008 (Table 12).

Large-scale disasters are usually recorded by the relevant commissions, while small-scale disaster losses are normally not calculated. In addition, there is no built-in system for calculations of damages and losses caused by natural disasters in the field of agriculture, otherwise the mentioned indicators would be much higher.

Around 30-35 thousand hectares of crops and perennial plantations are annually damaged by various natural disasters in Armenia, such as spring frosts and hail. Consequently, often sown areas, the volume of yield, its quality are reduced[53]. This has negative impact on the future productive activities and social status of agricultural operators. It often contributes to the reduction of the attractiveness of sub-sectors, as well as to migration from rural areas.

Expected changes

The effects of climate change are being felt around the world and Armenia is no exception. According to FAO estimates, by 2050, the volume of agricultural production should be increased by 60% and about 49% more food should be produced in order to provide food for the growing, prosperous population of the planet. However, agriculture is a major factor in climate change and suffers greatly from it. It emits a quarter of the GHG emissions.

[49] Guidelines for Reducing the Risks of Natural and Man-Made Disasters Causing Damage to Agriculture in the RA, UNDP, 2015. Link: https://www.un.am/up/library/Guidelines_risk%20reduction%20hazards%20in%20RA_arm.pdf

[50] RA Government protocol decision N15 on the adoption of concept for the prevention of agricultural damages caused by natural and climatological disasters, RA Government, April 13, 2017 Link: http://www.irtek.am/views/act.aspx?aid=89460

[51] Third National Communication on Climate Change, RA Ministry of Nature Protection, 2015, Link: http://www.nature-ic.am/wp-content/uploads/2013/10/3.Armenias-TNC_2015-ARM.pdf

[52] RA Government protocol decision N15 on the adoption of concept for the prevention of agricultural damages caused by natural and climatological disasters, RA Government, April 13, 2017 Link: http://www.irtek.am/views/act.aspx?aid=89460

[53] Ibid

Table 12: Damage to agriculture due to hazardous hydrometeorological phenomena, 1995-2018[54]

Year	Total damaged land, thousand hectares	Total damage, billion AMD	Total damage, in thousand US dollars
1995	86,959	17.0	41,881
1996	36,654	12.6	30,408
1997	129,819	26.5	54,049
1998	63,411	15.0	29,609
1999	43,026	11.3	21,175
2000	N/A	59.8	110,801
2001	83,500	23.9	43,129
2002	74,546	15.1	28,381
2003	48,667	82.6	142,770
2009	35,368	11.9	32,729
2010	17,474	35.5	95,006
2011	4,061	0.9	2,443
2012	2,219	0.5	1,220
2013	11,101	25.3	61,763
2014	24,286	17.9	43,037
2015	8,800	7.8	16,321
2016	23,100	33.6	69,929
2017	15,490	12.9	26,724
2018	14,650	13.4	27,744
Total		**423.5**	**879,119**

Climate change, such as extreme weather events, the spread of pests and diseases, biodiversity loss, degraded ecosystems, water scarcity, will only get worse as the planet warms. It will have a negative impact on food security and livelihoods, leading to forced migration. According to expert estimates, in 2050, crop yields worldwide may fall by 10-25%, grain prices may rise by up to 29%[55].

Climate change in Armenia is characterized by vulnerable ecosystems, arid climate, active external and desertification processes, and frequent natural disasters that make the country more sensitive to the effects of climate change. Over the last few decades, the intensity and frequency of climate dangerous weather phenomena has increased.

According to calculations made in different climate change scenarios designed for Armenia in 2030, 2070, 2100, a significant and continuous increase in temperature is forecasted for Armenia, especially in spring and summer months. Cumulative river flow will decrease by 12% by 2030, 25% by 2070, 40% by 2100 (compared to the norms of 1961-1990)[56].

Although GHG emissions are relatively small in Armenia, the living standards of the population, economic productivity and future economic development may be jeopardized by climate change. Armenia, as a mountainous country, is distinguished by vulnerable ecosystems, arid climate, active external processes, and frequent natural disasters. Given these circumstances, a more significant expression of climate change is possible in Armenia.

[54] Armenia. Assessing Vulnerability to Climate Change, Armenia Red Cross Society, 2014 Link: https://climateforumeast.org/uploads/other/0/570.pdf

[55] FAO’s work on Climate Change, Conference 2019, FAO, 2019. Link: http://www.fao.org/3/ca7126en/ca7126en.pdf

[56] RA Government protocol decision N14, as of April 6, 2017 on the Approval of National Disaster Management Strategy and Action Plan. Link: http://www.irtek.am/views/act.aspx?aid=89604

According to forecasts, the climate of Armenia can undergo huge changes, especially during the next 100 years. The temperature will rise, precipitation and snow cover, river flow and lake level will decrease, hot weather (droughts, rains), mudslides, floods will be observed more often. Climate change, and the closely related desertification phenomenon, has its own unique manifestation in Armenia.

Predicted climate change by 2050 in Armenia includes:

- Increase in average annual temperature by 1.6-2.2° C.
- Irregular changes in average annual precipitation. It is likely that the average precipitation in June-September will decrease by 7-10%, and according to some other estimates, the amount of possible summer precipitation will decrease by about 23%.
- Increase in the number of continuous dry days by 7-11%.
- Increase in the number of extremely rainy days by 22-32%[57].

The amount of annual precipitation and their distribution during the year is one of the main conditions for the efficient management of irrigated agriculture, in particular, crop and livestock sectors. Considering that only 7.6% of the agricultural lands of the Republic of Armenia and 32% of the arable lands are irrigated, the predicted climate changes, especially the decrease of precipitations during the summer months, can cause serious problems for the irrigated agriculture, and projected reduction of water resources - for irrigated agriculture.

According to Armenia's ''Third National Communication on Climate Change", the movement of agro-climatic zones is predicted to be 200-400 m by 2100, along with decrease of crop yields, soil degradation, decrease of fertility and increase of negative impact of dangerous hydro-hydrological phenomena.[58]

According to the World Bank's "Climate Change - Agriculture for the Country" report, a decline in crop yields is expected. In parallel, according to some scenarios, by 2030, the yield of the main agricultural crops will decrease by 8-14%. It is predicted that it will have a negative impact on pastures and grasslands. Pasture area and yield is projected to be reduced by 4-10%, and grassland yield - by 7-10%[59]. It is predicted that this change may be a stimulating factor for the development of crop diseases, pests and the spread of new species. Climate change in the livestock sector can also cause problems. In particular, dry-drought years can cause serious problems, in particular, in the organization of fodder production, declining summer pasture yields, and watering animals in summer pastures. It can also contribute to the development and spread of animal diseases.

[57] The RA climate change and agriculture country note, WB, 2012.
Link: http://documents.worldbank.org/curated/en/750371468208161919/Armenia-Climate-change-and-agriculture-country-note

[58] RA's Third National Communication on Climate Change, UNDP, 2015.
Link: http://www.nature-ic.am/wp-content/uploads/2013/10/3.Armenias-TNC_2015-ARM.pdf

[59] The RA climate change and agriculture country note, WB, 2012.
Link: http://documents.worldbank.org/curated/en/750371468208161919/Armenia-Climate-change-and-agriculture-country-note

3. National policy environment for climate change and agriculture sector in Armenia

3.1. Overview

Overall, there has been a significant shift in government policy to address and adapt to the challenges of climate change in agriculture in recent years, including issues of increasing intensity of hydrometeorological risks due to climate change. It should be noted that the sector policy related to the climate change adaptation shifts is more advanced than the mitigation related consideration. However, the work done in this direction is not yet systematic, but fragmentary, requiring a more consistent, coordinated approach to reduce the negative impact of climate change.

Agriculture is one of the most vulnerable sectors in terms of disasters, including climate change. However, there is a limited set of legal instruments that address climate change in agriculture, as well as disaster risk management challenges. The main legal documents addressing the challenges of climate change cover a variety of areas, including agriculture.

The legal framework in the Republic of Armenia, aimed at mitigating climate change, reducing GHG, increasing adaptation, consists of international treaties, conventions, relevant laws, Government decrees, strategic documents, and other legal acts signed by the RA which allow the government to implement the relevant policy and strategy. There are also a number of Government decrees on sectoral policies and strategies to address climate change challenges. These documents concern the use of water and land resources, the management of forests, especially, protected areas, the protection of the environment and biodiversity, the fight against desertification, and contain certain provisions dedicated to meeting the challenges of climate change. Nevertheless, they mainly do not raise/address the issue of mitigation of climate change from the agriculture sector.

3.2. Regulatory framework

Armenia has adopted a number of laws and Government decrees, developed and implemented national and sectoral development programs during the recent years, which are based on the principles of sustainable, low-carbon development.[60] However, there are no sectorial comprehensive policy and development programs for climate change mitigation in agriculture sector.

The regulatory framework for agriculture sector in Armenia, includes several laws, regulations, Government decrees, etc., however, the official documents do not effectively integrate climate change or the concepts of climate change mitigation and adaptation issues. They often do not directly address issues related to the climate change, including GHG reductions. On the other side, their effective enforcement could contribute to the reduction of GHG emissions.

The regulatory framework for agriculture sector in Armenia, including a number of laws, regulations, Government decrees, etc., often does not directly address climate change, greenhouse gas reductions, however, their effective enforcement has a positive impact on reducing emissions.

[60] RA's Third National Communication on Climate Change, UNDP, 2015.
Link: http://www.nature-ic.am/wp-content/uploads/2013/10/3.Armenias-TNC_2015-ARM.pdf

In this regard, it contributes to the implementation of government policies aimed at mitigating the impact of climate change.

Legislation

The main laws regulating the agriculture are:

- RA Land Code,
- Law on Phytosanitary,
- Law on Pedigree Livestock Breeding,
- Law on Organic Agriculture,
- Beekeeping Law,
- Law on Fodder,
- Law on Seeds,
- Law on Food Safety Law,
- Law on Protection of Plant Varieties,
- Law of Alcoholic Beverages with Raw Grapes Basis.

The following main laws and bylaws are related to climate change adaptation and mitigation.

Land code of the RA, 2001**:** the Code defines the legal basis for the improvement of state regulation of land relations, development of different organizational and legal forms of land management, increase of land fertility, land use efficiency, protection and improvement of environment favorable for human life and health, protection of land rights. It is stipulated that the possession, use and management of land must not harm the natural environment, the country's defense capacity and security, must not violate the rights and interests of citizens and other persons protected by Law. The Code addresses some issues related to the fertility of lands, including the humus content the management of agricultural lands, including natural tributaries.

The Code defines the problems of land protection, which include retention of land fertility, as well as preservation, improvement and efficient use of other useful characteristics of the soil. Protection of lands from water and wind erosion, floods, swamps, double salinization, hardening, desertification, other effects deteriorating the soil condition (Article 31).

The decree N 276-N on "**Approving the procedure for land monitoring conduction" was adopted by** RA Government in 2009. The procedure defines the problems of soil monitoring, including study of soil condition, assessment, timely detection of its change, prediction of these changes, prevention of adverse processes (soil condition is assessed by soil humus content, which determines soil type, structure, fertility, plant growth potential, as well as the amount of **carbon stored** in the atmosphere), collection of data on targeted land use and providing the necessary information to interested organizations.

The decision N 389-N on "**Defining the order of use of pastures and grasslands in the RA"** was adopted by RA Government in 2011. It is aimed to ensure comprehensive regulation of the sector, defining the conditions for the effective use of state-owned pastures and grassland management. The objectives of the decision are the protection of natural terrains, their sustainable and efficient use, restoration of productivity and creation of favorable conditions for improvement, prevention of deterioration of the quality characteristics of pastures and grasslands.

The procedure for state registration, import, use/application of pesticides and agrochemicals, including **fertilizers**, shall be established by the Law on Phytosanitary, as well as the relevant by-laws.

The "RA law on Phytosanitary, 2014" - defines the requirements for pesticides and agrochemicals as well as the state registration procedure, the requirements for natural and legal persons engaged in cultivation of agricultural lands, measures to protect the pollution of harmful residues of vital activity, basic nutrients of soil from storage.

In 2015, the RA Government adopted decree N 1195-N to recognize the **N 1899** decree on "**Approval of the technical regulation of production, packaging, circulation of pesticides, agrochemicals" adopted in 2005 as** invalid. The decree defines the requirements for the production, packaging, storage, transportation and circulation of pesticides, agrochemicals in the Republic of Armenia.

According to the Order N 756-N adopted in 2005 by the RA Minister of Health, on "**The storage, transportation, use, sanitary rules and norms of the sale of pesticides (pesticides**)", the hygienic requirements for the storage, conversion, application, sale of pesticides are presented by various methods, use, application procedure.

The Order N 256-N of the RA Minister of Health adopted in 2005 on **"Production, storage, conversion, sanitary rules of sale, normal approval", defines** the hygienic requirements for the production, storage and conversion of mineral fertilizers. The general requirements for the safety of the order state that after mineral **fertilizers** are used in the soil, in the air (in the presence of cyclic compounds), in water, in agricultural products, the content of dangerous toxic substances shall not exceed the hygienic norms.

"RA Law on Fodder", adopted in 2014, regulates the import of fodder additives, export, production (including primary), production safety, storage, transportation, use, sale, labeling, packaging and advertising relationships.

The "**RA Law on Pedigree Livestock Breeding "** was adopted in 2005 and regulates the intensification of animal husbandry, stabilization of pedigree materials, creation of new cycles of farm animals, attribution, use, preservation of breeds at risk of non-compliance.

The decree of RA Government N 954-L on **"Approving the identification and registration program for cattle in the RA"** was adopted in 2020**.** The inaccurate information of number of livestock in the country has a negative impact on food security (disease control, forecasts of animal origin products, etc.) and food safety. By this decree, the Government targets cattle, and subsequently, small ruminants, to initiate calculation for all interested parties to create an electronic information platform.[61]

The lack of animal identification and registration system also does not allow for effective organization of systematic pedigree breeding work, increasing the share of animals in the country with desirable indicators, in particular, in terms of improving the breeding of pedigree and artificial insemination. The introduction of the system will provide an opportunity to obtain more reliable and accurate information about the number of livestock, efficiently and systematically organize pedigree breeding work. This shall have a positive impact on government efforts to mitigate climate change.

[61] RA Government decree N 954-L on Approving the identification and registration program for cattle in the RA, RA Government, June 11, 2020. Link: https://www.arlis.am/DocumentView.aspx?DocID=143439

The Law on **"Organic Agriculture"** was adopted in 2008. The law regulates the relations related to the production, storage, processing, transportation, sale of organic agricultural products, as well as the harvesting of wild plants. The law describes the principles for the management of organic agriculture, defining the practice as one that is in harmony with agricultural ecosystems and implemented in compliance with the requirements of relevant technical regulations and other normative documents. It defines the main principles for the organic agriculture, including the "establishment of a favorable environment for the preservation of biodiversity, as a result of selective breeding of plants and livestock, as well as the reduction of risks caused by human activity. Other principles include e.g. the improvement of the soil's physical, chemical and biological qualities, and the maintenance of fertility by natural means (crop rotation, organic fertilization, creation of forested zones to combat erosion, etc.); etc. The law does not possess any provisions of organic agriculture on possible impact on the reduction of greenhouse gas emissions or on agriculture resilience to climate change.

The Protocol Decision No. 15 on **" On the adoption of concept for the prevention of agricultural damages caused by natural and climatological disasters "** was adopted in 2017 by RA Government. The concept is due to the need of increasing number and intensity of agricultural disasters, including climate change-related disasters, in particular, vulnerable natural disasters, and the need to mitigate them. The main goal of the concept is to determine the main directions of the policy in the field of increasing the resistance of agriculture from natural disasters, mitigating the risks of the sector and preventing the damages. The concept substantiates the need to prevent damage to agriculture from natural disasters and proposes the preferred main directions of prevention of damage from natural disasters in Armenia and mitigation of their consequences. Nine main preferred directions have been outlined, appropriate solutions have been proposed; the main types of target means, the possibilities of their application and implementation have been described.

The Protocol Decision N 23 decision of RA Government **"Approval of the Strategy for Combating Desertification in the Republic of Armenia, National Action Plan"** was adopted in 2015**.** The strategy identifies the phenomena of desertification in the territory of the Republic of Armenia, defines the criteria and features of desertification, identifies the problems of desertification, their causes and factors, as well as the link between desertification and climate change. The strategy proposes complex measures aimed at promoting their prevention / elimination or mitigation, in particular, legislation, improvement of the management, monitoring and education systems, ensuring public awareness. One of the strategic priorities of the document is to increase the efficiency of land management, to improve the use of water resources, to raise public awareness on the solutions and international cooperation.

The decision N 68-L on **"Approving of the concept paper and action plan on improving the efficiency of agricultural land use in RA"** was adopted by RA Government in 2020. The goal of the Concept Paper is to specify the main directions of the state policy aimed at increasing the efficiency of agricultural land use, the utilization of which will boost the level of agricultural land use, efficiency of agriculture production and the level of food safety in the country. The proposed solutions of the concept guide the policy towards solving the issue of abandoned lands, creation of a land bank and legal regulation of its activity, implementation of long-term programmes targeted at land consolidation basing on the international best practice, creation of databases on the basis of digitalized maps of agricultural lands and agrochemical studies and proposal of mechanisms for their application, stock-taking and digitalization of agricultural land plots, including unused lands is a priority for achieving the proposed solutions. This should be accompanied by improved package of land legislation and promotion of new contacts between the land owners and land users.

Conventions and international agreements

Since independence, the Republic of Armenia has acceded to key conventions related to climate change and the environment. Armenia has been doing significant work on climate change mitigation and adaptation.

In 1993, Armenia ratified the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force in 1994. In 2002, the Republic of Armenia ratified the Kyoto Protocol. In 2017, the Paris Agreement and the Doha Amendment to the Kyoto Protocol were ratified by the RA National Assembly.

Armenia's obligations under these agreements derive from its status as a developing country not included in Annex I to the UNFCCC. The position of the country under the Convention and the Paris Agreement is formulated in the document "Intended Nationally Determined Contributions ". This was approved by the RA Government in 2015 by the protocol decision N 41 in 2015 and was submitted to the UNFCCC. In particular, the mentioned decree gives preference to the direction of adaptation to climate change and presents the planned mitigation actions / contributions defined at the national level. The decision stipulates that climate change mitigation measures should not lead to social and economic regression, but rather should contribute to the socio-economic development of the Republic of Armenia, based on the ecosystem approach. In order to ensure the fulfillment of the obligations defined by the international environmental agreements, the RA Government adopted a protocol decision on "Approving the list of measures for the fulfillment of the obligations of the RA arising from a number of international environmental conventions" (2016, N49). This decision defines the list measures for 2017-2021 implementation of the obligations and provisions of the UNFCCC; and responsible agencies have been appointed. The GHG emissions cadaster is implemented in accordance with the UNFCCC Articles 4.1 and 12 and according to the point 8 of the above-mentioned protocol decree (N 49 of the 08.12.2016).

During these years, significant work has been done by the Republic of Armenia in fulfilling its obligations under the Convention. Armenia has developed and submitted four national communications to the Secretariat of the Convention (1998, 2010, 2010, 2015 and 2020) and three biennial update reports (2016, 2018, 2021), as well as separate National GHG Inventory reports.

3.2.1. Regulatory bodies

Taking into account the multi-sectoral nature of the climate change issue and the framework convention aimed at its solutions, the innovative approaches and mechanisms being developed in the fight against climate change and the effective participation of the Republic of Armenia in them, in 2012, interdepartmental coordination council was established[62]. **The Council is chaired by the RA Minister of Environment.** An important task of the Council is to coordinate the implementation of the obligations assumed by the Republic of Armenia under the Convention, to submit proposals on measures to fulfill the obligations and provisions of the Convention, to provide advice, to evaluate the implementation process.

Taking into account that the above-mentioned council has not been functioning for more than a year, mainly conditioned by the change and structure of the RA Government, the latter has circulated a new draft decree in 2021 to "Establish an Inter-Agency Coordinating Council for the Implementation of the Requirements and

[62] RA Prime Minister decree N955-A on approving the composition and rules of procedure of the inter-agency coordinating council on implementation of requirements and provisions of the UNFCC, RA Government, 02 October 2012. Link: https://www.arlis.am/DocumentView.aspx?docID=78543

Provisions of the UN Framework Convention on Climate Change and the Paris Agreement"[63] is currently circulated for the Governmental approval. According to the draft decision, it is envisaged to reserve the competence of the chairman of the council to the RA Deputy Prime Minister, to expand the scope of competence of the council, to clarify the structure, the procedure, envisaging permanent inter-agency working groups, as well as the possibility of creating temporary inter-agency working groups.

RA Ministry of Environment

The preparation of bi-annual progress reports on RA national communications under the Convention is coordinated by the RA Ministry of Environment (MoE) as the UNFCCC National Coordinator[64].

The tasks of the Ministry include to protect and improve the environment, water, soils, entrails, fauna and flora of the Republic of Armenia, to prevent or reduce natural or man-made negative effects on it, as well as sustainable management of specially protected areas and forests, development and implementation of policies in the areas of conservation, protection, reproduction and use, aimed at addressing climate change issues, including adaptation and implementation.

Department of Climate Policy

In 2019, by the decree of the Prime Minister of the RA (N 1785-L), a number of changes were made in the structure of the Ministry of Environment of the RA and a **Department of Climate Policy** was established. Its functions include development of state policy, programmes, strategies, legal acts, guidelines on climate change mitigation and adaptation and ensuring the process of their implementation; participation in the implementation of the provisions and obligations set out in climate change international conventions, treaties and agreements and decisions made within their framework.

“Hydrometeorology and monitoring center " SNCO of the RA Ministry of Environment

The main subject of activity and objectives of the SNCO are to promote the protection of the components of the environment: atmospheric air, water resources, flora and fauna, including specially protected areas and forests, soils, entrails, natural resources and the rational use of natural resources through by observation of the components of the environment and the factors affecting them, creating sufficient data to assess the situation, registering, analyzing, providing and maintaining thereof.

One of the functions of the organization is to monitor the environment, including atmospheric air pollution, physical effects on the air, natural phenomena in the atmosphere, such as climate change, ozone depleting substances, other anthropogenic effects and observations of water, carrying out studies of quantitative properties, as well as other impacts and phenomena deteriorating the state of water resources, studies on the state of soil pollution and qualitative changes.

[63] Draft Resolution of the Prime Minister of the RA on the Establishment of an Interdepartmental Coordination Council for the Compliance with the Requirements and Provisions of the Paris Framework Convention on Climate Change, its composition, approval of the Rules of Procedure. Link: https://www.e-draft.am/projects/2979/about

[64] RA’s 4th National Communication on Climate Change, UNDP, 2020
Link: http://www.nature-ic.am/hy/publication/Fourth-National-Communication-on-Climate-Change/11676

RA Ministry of Economy

The Ministry is the authorized body for the development and implementation of agrarian policy in Armenia. The Ministry with the current structure was formed as a result of the unification of the RA Ministry of Economic Development, the Ministry of Investments, the RA Ministry of Agriculture in 2019. In accordance with the Law on making amendments and addenda to the Law on the Structure and Activities of the Government adopted by the National Assembly in 2006, the Ministry of Economy of the Republic of Armenia includes 14 main professional structural subdivisions, 10 professional structural subdivisions supporting the Ministry, 4 offices and 1 subordinate body.

The main professional structural subdivisions of the Ministry, responsible for the development, implementation, coordination and evaluation of the results in the field of agriculture are:[65]

1. **Department of Primary Agricultural Production** - the main goal is to develop the main directions of the state policy of development of the spheres of animal husbandry, fish breeding, beekeeping, crop production.
2. **Food Safety Department -** the main task and goal is to develop policies for the development of food security, veterinary and phytosanitary spheres of the republic and to formulate a unified state policy.
3. **Food Security and Agro-Processing Development Department** - the main task and goal is to develop the main directions of the policy of agro-processing, development of agro-business and agribusiness sectors and to formulate a unified state policy.
4. **Department of Agricultural Programs Elaboration, Resource Use and Cooperative Development** - the main task and goal is to develop the main directions of the agrarian policy of the republic and to formulate a unified state agrarian policy.
5. **Department of Agricultural Extension, Innovation and Monitoring** - the main goal is to ensure effective cooperation of the science-consultant-farmer chain in the field of agriculture, study of innovations, implementation of localization-monitoring. One of the tasks of the department is the design, implementation and coordination of trainings, as well as specialist trainings, development of agricultural information system, awareness and localization on new agricultural technologies and innovations.
6. **Agricultural Programs Implementation Department** - the main tasks are to ensure the coordination of programs implemented with the financial support of foreign states and international organizations at the expense of the RA state budget, to ensure cooperation within the framework of international agreements in the field of agriculture.

"Center for Agricultural Services" SNCO of the RA Ministry of Economy

The purpose of the organization is:

- Ensuring the production of high-quality livestock products and raw materials from the veterinary point of view, establishing stable interstate economic ties, promoting the export-import process;
- Detection, registration of plant pests in the country through research, monitoring, verification of the distribution area and economic thresholds of pest, prevention of the spread and professional support for these works;
- Obtaining a high, healthy crop of agricultural crops, as well as conducting laboratory tests of fertilizers and bio-stimulants and evaluating their quality indicators.

[65]RA Ministry of Economy, Charters. Link: https://mineconomy.am/page/74

One of the functions of the SNCO is to study and assess the agrochemical condition of agricultural lands, implementation of measures to supplement the lack of nutrients in the lands and organize the awareness programs for state and local self-government bodies, participation in the elaboration of programs for measures to maintain the fertility and continuous reproduction of agricultural lands and implementation of the measures envisaged within the programs.

There are a number of non-state organizations that support farms. **A leader in the field is the "Center for Agribusiness and Rural Development", the CARD Foundation**. The foundation operates in four main areas: agribusiness and marketing, rural development, food security and veterinary medicine. CARD implements support programs for agricultural development, promotes modern efficient agricultural technologies, the use of agricultural machinery and equipment, supports agricultural processing companies to improve the competitiveness of their products in local export markets, helps to improve food safety at all stages of the production cycle. Currently, CARD has 18 agricultural service centers in the regions, the nature of the services provided by the latter is conditioned by the agricultural orientation of the location.[66]

Functions of state bodies

Regarding the functions of the aforementioned state bodies and organizations coordinating the sector, in general, climate change issues are not included in their functions. In the field of agriculture, both in terms of climate change mitigation and adaptation, both within the sector and across different departments, cooperation and data exchange agreements are not in place at the required level.

An important issue that concerns the agricultural sector in general, and climate change mitigation and adaptation processes of the sector, is the issue of reliable information, data collection, analysis, management and providing them to the stakeholders in the sector. Access to reliable and accurate information, timely decision-making is a challenge for both the government and local levels, including farms. What is available often lacks consistency, compatibility, accuracy and time relevance. It is an obstacle in policy development, implementation, decision-making and targeted use of resources. In general, the availability of systematic and reliable information to policy-makers in the decision-making process makes it possible to more effectively target policy implementation and organize the work of state bodies. Reliable data and strong institutional mechanisms can help to identify feasible, effective options for climate change mitigation in agriculture and land use.

One of the problems in this regard is the insufficient level or lack of use of stakeholder skills for the analysis of data obtained at the macro level, technically advanced infrastructure and digital tools, including predictive analytical tools. The availability of high-quality data, along with the necessary analytical tools and capabilities, is essential for industry stakeholders in organizing fact-based planning.

One of the serious problems is the lack of information on the needs of all participants in the agricultural sector, including farms, service companies, public-private consulting organizations, government employees, climate change mitigation, adaptation. The analysis of the situation showed that there are obvious problems in the exchange of data and knowledge between the various stakeholders in the agricultural sector, including in digital form.

In general, the current public-private agricultural advisory services do not have sufficient institutional, human and financial resources to adequately support climate change adaptation and mitigation.

[66] The Center for Agribusiness & Rural Development (CARD). Link: www.card.am

3.3. Recent strategic plans and roadmaps

Ensuring the economic development of the RA agricultural sector main directions strategy (2020-2030)

One of the main documents of the agricultural policy is the "Ensuring the economic development of the RA agricultural sector main directions strategy (2020-2030)" approved by the RA Government in December, 2019[67]. The document defines the vision of the RA Government for the next ten years. That is, to have a sustainable, innovative, high value-added, environmentally friendly outputs that guarantees the well-being of rural people. The vision is reflected in the strategy, which presents in detail the main priorities of the state in agricultural policy, defines the scope of priority tasks and the action plan for the implementation of the given strategy.

The strategy is based on seven key principles and is aimed at inclusive growth, gender equality, and institutional stability.

Among the seven principles mentioned are diversification/risk management, adaptation to climate change and environmental sustainability. It is proposed to introduce a risk management system - hail protection and water conservation systems, afforestation belt, appropriate technological investments, complete agricultural insurance. This is aimed to ensure climate change awareness, adaptation, mitigation, resource sustainability functions. The objectives are to improve climate change monitoring, smart agricultural practices, to ensure the development of the agricultural sector by applying sustainable use of resources, including the introduction of best practices in water and land resources management.

The document sets out the seven main priorities of agrarian policy in the coming years:

1. Increase the competitiveness and efficiency of the agricultural sector;
2. Ensure food safety;
3. Improve food security and nutrition;
4. Develop local markets and increase export opportunities;
5. Develop human and institutional capacities in the field of agriculture;
6. Support the sustainable development of rural communities;
7. Promote digital agriculture and technological innovations.

The document raises the problems of agricultural development and challenges, emphasizing natural disasters and climate risks that can jeopardize the normal production process of agricultural products. Overall, there are not yet developed state/clearly institutionalized structures target to mitigate existing risks.

The Strategy reflects the following:

1. Introduce an agricultural insurance system (included in the 2020-2022 action);

2. Develop and introduce an effective anti-hail system (included in the 2020-2022 action);

3. Explore and develop various opportunities to adapt to climate change increase resilience (e.g., drought tolerant varieties, modern agricultural practices, localization of "smart", "sensitive" technologies and practices adapted to climate change).

[67] Ensuring the economic development of the RA agricultural sector main directions strategy (2020-2030), Ministry of Economy of RA. Link: https://mineconomy.am/page/1467

In the document, the development of digitized maps of agricultural lands on the basis of large-scale agrochemical research is defined as urgent priority - included in the 2020-2022 action plan. This will enable the creation and use of agrochemical databases. With the support of FAO, a website, the Soil Information System of Armenia (http://armsis.cas.am/) has already been created. It targets to include digital maps on soil fertility, nutrients, climate change, soil organic carbon content, soil degradation and erosion.

Digitized agrochemical maps will enable compiling scientifically grounded recommendations and guidelines for crop fertilization. Through its use, the farmers and other beneficiaries will be able to get information about the amount of the nutrients in the soil, apply balanced fertilizers and follow the state of land degradation. As a result of application of the digitized data soil fertility, profitability will increase and the amount of GHGs from nitrogen fertilizers will reduce.

The 2020-2022 action plan of the strategy includes the development of a program for registration and identification of livestock. It is an important tool for improving the accuracy of livestock forecasting, monitoring the movement of animals, revealing the hidden population, developing insurance mechanisms. It will help ensure traceability regarding mandatory slaughterhouse activities, contribute to the development and implementation of appropriate state support programs for artificial insemination. It will enable the development of effective measures to accurately calculate the amount of GHG emissions from agricultural animals, as well as guide the selection of animals in a direction that will reduce GHG emissions through appropriate pedigree works.

One of the seven strategic priorities defined for Armenia's agriculture sector is to promote digital agriculture and technology innovation, which is a cross-cutting element supporting the other priorities. The action plan of the strategy envisages the adoption of a separate digital agriculture strategy. The digitalization of agriculture in Armenia and the adoption of many innovations, among other positive effects, will lead to a significant increase in the productivity of farms. This shall strengthen resilience to climate change and disasters, strengthening ties with high-value markets, improving food quality, improving resource utilization. On the farm level, digital technologies can support managing operations and functions by collecting, processing, storing, and disseminating information.

Moreover, digital technologies can contribute to delivering more streamlined agricultural production, the part of digital agriculture often called 'precision agriculture'. It is based on a resource-efficient approach which could also lead to great benefits in terms of environmental issues, e.g., through more efficient use of water, or optimization of treatments and inputs reducing the use of fertilizers, pesticides, etc. ('doing more with less').[68]

One of the important actions of the Strategy is the creation of a digital farm register. It will enable the creation of a unified information system, where detailed and reliable information on the economic activities of farms will be posted and regularly updated. The system is an effective tool for the government to develop and implement agricultural policy, including climate change mitigation and adaptation. It is also a functional tool for collection of reliable date at farm level which could include information about land parcels, land use, animal herds/flocks, information about usage of agricultural inputs, such as fertilizers, pesticides, etc.

[68] Draft Digital Agriculture Strategy of the RA 2021-2030, RA Government decision.

Program of the RA Government

According to RA Government's program N 65-A approved in 2019, the important directions of the agricultural policy are the increase of agricultural efficiency, enhancement of food security level, import of modern technologies, increase of export volumes, regarding all representatives included in the agricultural value chain (such as small households and agricultural cooperatives), and increasing the profitability of exporters[69].

The program of the RA Government aims at the targeted use of abundant agricultural lands, increasing the level of access to irrigation water, application of new technologies in the field, upgrading of agriculture machinery and equipment, support for the introduction of agri-food system equipment, food safety systems, seed breeding and intensive horticulture, control and management of crop pests and animal diseases, development of non-agricultural activities in rural communities, introduction of insurance system, creation of favorable conditions for economic activities in agriculture, targeted and systematic use of natural pastures.

“The budget message of the RA Government in 2021”[70] stipulates that the economic development policy of the RA will be anchored on five pillars, which guide the economic priorities of the government. The 5th pillar is the increase of agricultural efficiency, the increase of incomes of the subjects included in the whole agricultural value chain - farms, cooperatives, agricultural processors, service infrastructures. In this regard, a special goal is to increase the level of food safety, as well as in the context of the effective use of agricultural resource potential, the introduction of advanced technologies, mitigation of climate risks.

RA 2014-2025 Strategic Perspective Development Plan

One of the sectoral priorities subject to direct policies of RA 2014-2025 Perspective Strategic Development Plan[71] is agriculture and rural development. Some of the potential development prospects of the sector, which are included in the strategic document, are the following:

- Development of economies of scale using intensive technologies;
- Sustainable food supply for the population and satisfying the demand for agricultural raw materials in the agro-processing sector;
- Increase of gross output in agriculture due to increase of labor productivity;
- Relative reduction of the number of people employed in agriculture and use of a part of the surplus labor force through agricultural services and training in non-agricultural activities;
- Dominance of production of agricultural products with high added value in the intra-sectoral structure of crop production;
- High level of food security of the population of the Republic, ensuring self-sufficiency of essential food products;
- Reducing rural poverty and emigration.

[69] RA National Assembly Decision N 65-A on approval of the RA Government program, RA Government, February 8, 2019. Link: https://www.arlis.am/DocumentView.aspx?DocID=128276

[70] “Budget message-explanation of the RA Government for 2021”, Ministry of Finance of the RA Link: https://minfin.am/hy/page/petakan_byuje_2021t

[71] RA 2014-2025 Strategic Program of Prospective Development, the GoA Link: https://www.gov.am/am/prsp/

3.4. State support programs to agriculture

Starting from 2017-2018, the Government of the RA has changed the directions of support for agriculture, which is currently mainly targeted at the development of agriculture equipped with the latest technologies, in particular. These programs are based on the vision of promoting high-value, innovative, export-oriented agriculture that will create and develop agribusiness in line with modern requirements [72].

Thanks to those programs, the volumes of investments in the field of agriculture have sharply increased. In 2019, about 43 billion AMD of capital investments were made in the field of agriculture, 2.6 billion of which were within the framework of state support programs. This has exceeded the corresponding indicator by about 1.8 times in comparison to 2018. In 2020, the volume of capital investments in the sphere made about 46 billion AMD. In 2019, the GoA allocated about 54.7 billion AMD to agriculture within the framework of state support programs, and about 108.2 billion AMD in 2020. Within the framework of the mentioned programs, in 2019, about 53 ha of intensive orchards were established. In 2020, this indicator has increased tenfold and made about 518 ha. Within the framework of state support programs (2019-2023) provided for the development of cattle breeding, sheep breeding and goat breeding, in 2019, about 304 heads of CCP and 203 heads of ONE were imported to the Republic, and in 2020 - respectively 391 and 672 heads[73].

These programs do not directly address climate change, but the implementation of these programs will have a positive impact on climate change mitigation, as well as adaptation and mitigation.

Based on analysis, it is proposed to include the concepts of climate change mitigation and adaptation in agricultural development programs as well as in state support programs.

1. **"Loan interest rate subsidy program for the agricultural sector" -** the main goal is to partially subsidize the interest rates on loans provided to individuals and legal entities engaged in the agri-food sector of the country, to improve the capacity of businesses, to introduce modern technologies, to increase the efficiency of agriculture by improving lending conditions.

2. **"State support program for the construction, reconstruction and technological re-equipment of small and medium-sized "smart cattle-breeding farms".** The main goal is to improve the raising of the animals, thus increasing the productivity of animals. Within the framework of the program, the state will reimburse the expenses of the beneficiaries who have built or reconstructed "smart" livestock farms.

3. **"Development of cattle breeding in the Republic of Armenia for 2019-2024"** - the aim is to provide affordable conditions to cattle breeders in Armenia. In particular, this refers to partial loan interest rate subsidies to supply herds. This will help to replenish herds of unknown origin, not suitable for reproduction and low-yield through cross-breeding. The aim is to improve the productivity of local animals, increase the volume of milk-meat production, reduce the cost of milk-produced meat, making it more competitive with similar imported products. During the implementation of the program, the cattle breeders will have the opportunity to acquire about 10 thousand highbred cattle, depending on the state support, the cost of obtaining the animal, gender and age group.

   The program will provide an opportunity to increase the high-breed value of herds and to restore the selective process in cattle breeding. As a result, by intensifying the cattle breeding branch, the

[72] State aid programs in the field of agriculture. Link: https://mineconomy.am/page/1338
[73] Ministry of Economy of RA

competitiveness increases. Animals with high pedigree-production characteristics provide higher productivity in a shorter period, thus reducing the cost of production.

High breed animals reach slaughter weight faster; they are slaughtered 3-4 months earlier than local animals, so their breeding season is 25% shorter, which reduces methane emissions [74]. In the case of breeding prematurely highly food-producing animals with the same amount, more production is obtained in a shorter period of time or under a shorter life span of the animals. Such animals will be exploited for a shorter period (20% less), resulting in less methane being released into the atmosphere.[75]:

Overall, the implementation of this program, as well as the state support program for the development of sheep and goat breeding, creates an opportunity to reduce GHG emissions.

4. **"Co-financing program for introduction of modern irrigation systems” -** the aim is to promote the introduction of effective methods of irrigation in agricultural lands. In this context, state support is provided for the introduction of drip irrigation and irrigation systems, partial reimbursement of interest on individuals and legal entities engaged in cultivation of crops at the discretion of the business. The implementation of the program enables the efficient use of water resources used for irrigation, to manage and reduce the volume of fertilizers used, to drastically reduce the amount of water erosion caused by irrigation. It will also have an impact on reducing the energy resources used for irrigation, improving crop quality, and more effectively fighting diseases and pests.

5. **“Subsidization of interest rates of loans for the implementation of anti-hail nets for the agricultural sector of RA” program -** the main goal is to promote the introduction of anti-hail nets in agriculture through state support to mitigate the risks of losses in the agricultural sector. This will contribute to effective protection of orchards from hail, increase the income of farmers and increase the efficiency of fruit growing.

6. **"State support program for the establishment of intensive orchards and berry fields cultivated in Armenia with modern technologies" program -** the aim is the development of fruit growing and viticulture, increase of production volumes of grapes, fruits and berries, replacement of fruits and berries import and increase of export volumes. It is envisaged to support the establishment of orchards at the expense of the RA state budget.

7. **"The program of subsidization of the interest rates of loans in agro-processing sector for procurement of agricultural raw material"** - the main goal is to increase the level of access to credit by subsidizing the interest rate loans to legal entities engaged in the field of agro-processing industry, individual entrepreneurs.

8. **"State support of leasing of agricultural machinery” programme** - the main goal is to supply agricultural machinery to farmers on affordable terms, in particular, using leasing mechanisms.

9. **"State support for financial leasing of agricultural and food equipment in the Republic of Armenia"** - the main goal is to provide equipment to agribusiness operators on affordable terms, in particular, using equipment using financial leasing mechanisms. This will create preconditions for increasing the production of agricultural and processed products, ensuring high quality competitiveness in

[74] “RA’s 4th National Communication on Climate Change”, UNDP, 2020.
Link: http://www.nature-ic.am/hy/publication/Fourth-National-Communication-on-Climate-Change/11676
[75] Ibid

accordance with international standards. This is aimed at increasing exports, as well as replacing imported products with local ones.

10. **"State support program for sheep and goat breeding in the RA for 2019-2023" -** within the framework of the program, it is envisaged to provide state support to provide access to high-breed small cattle by partially subsidizing the interest rate of loans provided for the purchase of high-breed cattle or reimbursing the incurred expenses.

11. **"State support program for the introduction of small to medium-sized greenhouses" -** the aim is to increase the area of greenhouses and production volumes through state support for the construction of small and medium-sized greenhouses and their technological protection. This will help increase the level of competitiveness of the local products, contributing to the increase of incomes of farmers.

12. **"State support for the implementation of a pilot program for the introduction of an insurance system in the field of agriculture."** In the process of mitigating the losses of businesses from natural disasters, it is important to create preconditions for the introduction of insurance system in the agricultural sector. For this purpose, the above-mentioned program is of high importance. The main goal is to clarify the mechanisms of agricultural insurance, to implement a policy for risk management in the agricultural sector as a result of the introduction of a comprehensive system. The amount of insurance premium is conditioned by the location of the insured area, according to the number of 5 risk zones. 5 levels of compensation costs have been selected based on the lowest possible production costs per hectare, according to the insured crops. Within the framework of the program, apricot, grape, peach, apple orchards, cereal crops (autumn/spring wheat, barley, oats) are insured regarding hail and fire, spring frost.

13. **"State support program to promote winter wheat in the Republic of Armenia"** - the main goal is to mitigate the economic consequences of the coronavirus by partially subsidizing or compensating the costs of winter wheat seeds, ensuring the availability of seeds with high agro-economic indicators. The aim is to enhance productivity, promote crop rotation and increase the crop fields, including usage of uncultivated land, leading to increase of the volumes and incomes of households from autumn wheat. The program covers Shirak, Syunik, Gegharkunik, Lori, Aragatsotn, Tavush and Kotayk regions for 2020-2021 period.

14. **"Measures to increase the fertility and agrochemical research of soil" -** the aim is to increase the level of fertility of each land through agrochemical field-laboratory research of agricultural lands. This will help develop fertilization measures to improve it and ensure a significant increase in crop yield. The implementation of the program enables having agrochemical maps of lands in the communities, scientifically substantiated recommendations of crops. In the result, the fertilizers will be used sparingly, purposefully, the decline of soil fertility will be prevented, the unbalanced use of fertilizers will be reduced.

15. **"Livestock vaccination program"** implements animal-epidemiological measures for the prevention of infectious diseases of animals, including animal-to-human infectious diseases, for the following diseases: brucellosis, anthrax, foot and mouth diseases, varroosis of honey bees, etc.

16. "**Plant protection measures program in the Republic of Armenia" -** the program is used to ensure a stable phytosanitary situation in the country. It includes the implementation of plant disease and pest control activities.

3.5. Perspectives of development of the agriculture sector

The prospects for the development of the agricultural sector are summarized in the "The Strategy of the Main Directions Ensuring Economic Development in Agricultural Sector of the Republic of Armenia for 2020-2030" and adopted by the Government of Armenia [76].

Vision and main directions of agricultural development

The document defines the vision of the RA Government for the next ten years. That is, to have a sustainable, innovative, high value-added, environmentally friendly output that guarantees the well-being of rural people. The strategy presents in detail the main priorities of the state in agricultural policy, defines the scope of priority tasks and the action plan for the implementation of the given strategy. The strategic document sets out the main directions of agricultural development.

To implement the strategic vision for the next ten years, an action plan has been developed (24 actions), aimed at the growth of agricultural production, the development of rural areas, and the increase of Armenia's competitiveness in the world economy. Through the implementation of the strategy, the government envisages improving the state of basic agricultural resources, especially land resources, creating favorable conditions for economic entities, increasing competitiveness, developing farms, improving the agro-food system with the use of affordable mechanisms, improving the conditions of selling products, supporting the introduction of modern methods and technologies in agricultural production-service processes, creating preconditions for the full implementation of the insurance system in agriculture.

Target indicators

It is envisaged to have certain improvements by 2029 such as: increase in the volume of gross agricultural output to 1,802 billion AMD; the average income of one farm rising to 5.0 million AMD instead of the current 0.64 million AMD; reduction in the share of uncultivated arable lands to 25%; growth of the share of irrigated arable lands to more than 40%; the export volume of processed agricultural products to USD 1.0 billion, growth in the global food security index to 75 (as calculated by The Ministry of Economy, Armenia's profile is not yet included in official ranking of The Global Food Security Index (GFSI)).

The Ministry of Economy of the RA foresees that as a result of the implemented policy and programs, in the medium term, 3.5-5.5% annual growth of gross agricultural product will be ensured.[77]

The strategy is quite ambitious, it anticipates radical reforms, however, the planned measures, and resources (about 36.4 billion AMD) may not be enough to implement it. Taking into account the problems of the sphere, in order to achieve these goals, it is necessary to join the efforts of the government, donor community and private sector. In particular, to carry out serious structural and institutional reforms, provide government support through policy design. Ensure subsidy mechanisms and other relevant tools support to development of public-private sector collaboration which will increase efficiency and attract private investment.

The effective enforcement of regulatory framework for agriculture sector in Armenia can directly and indirectly reshape the climate change effects from agriculture sector and promote effective climate change mitigation actions.

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[76] "The Strategy of the Main Directions Ensuring Economic Development in Agricultural Sector of the RA for 2020-2030", Ministry of Economy of the Republic of Armenia. Link: https://mineconomy.am/page/1467

[77] Agrarian Policy, Ministry of Economy of RA, 2019. Link: https://www.mineconomy.am/page/1326

4. Agricultural sector emissions in Armenia

If current trends of agriculture production and management are retained in future ("Business-as-usual" scenario), Greenhouse Gas (GHG) emissions from Agriculture sector in Armenia are forecasted to reach the level of 3,820 Gg CO_2 eq. in 2030, 58.7% of this being attributed to the Livestock sector and the remaining 41.3% - to the Land management. This is an estimated 98.1% increase of GHG production from 2017.

Livestock sector has relatively higher level of GHG emissions. The most significant emitter of GHG emissions is *cattle.* It is estimated that introduction of measures and activities following international best practices ("Mitigation" scenario), the level of emissions from livestock management in Armenia can be substantially reduced. Mitigation activities for livestock sector management include improving the breed (with increased meat and milk production) for the biggest emitter, introduction of optimal feeding regime for chosen breeds and application of anaerobic digestion (AD) for manure management[78]. As a result of such activities, the estimated GHG production level by 2030 is forecasted to reach 1,364 Gg CO_2 eq. In contrast to the 108.1% increase of GHG emissions from Livestock if no mitigation actions are taken, the mentioned activities are forecasted to result in only a 28% increase of GHG production as compared to year 2017.

The "Mitigation" scenario for land use and management considers changes in the agricultural production methods and incorporation of practices aimed at the reduction of the GHG production in sub-categories of land. It was not possible to calculate the GHG production from land use and management because no quantitative data, which needs to be used in the "Mitigation" scenario is available for this category. Instead, best practices were observed and those activities which are deemed more relevant to the context of Armenia are presented in section 4.2 Managed soils.

4.1. Overview of GHG emissions from agriculture sector in Armenia

Total GHG emissions from Agriculture sector in Armenia in form of CH_4, N_2O and CO_2 totaled to 1,965 Gg CO_2 *eq.* in 2017[79]. 49.5% of this was generated from enteric fermentation and 1.8% - from manure management in form of CH_4. The N_2O emissions accounted for 4.8% from manure management and 43.4% from soils. The rest of GHGs are produced from biomass burning and as CO_2 emissions from urea application. The highest CH_4 emissions from enteric fermentation (87%) are from *cattle*, and highest N_2O emissions (90%) are from managed soils [80].

Given the current emission trends, as well as the trends in increase in agricultural production, which is highlighted in "The Strategy", it can be assumed that GHG emissions from agriculture sector will increase by year 2030.

This study is aimed at analysis and suggestion of potential mitigation actions ("Mitigation" scenario) in order to reduce GHG emissions from agriculture sector in Armenia by year 2030 as compared to the "Business-as-usual" scenario.

[78] "National Greenhouse Gas Inventory Report of Armenia 1990-2017", UNDP, 2020.
[79] "National Greenhouse Gas Inventory Report of Armenia 1990-2017", UNDP, 2020.
[80] "2006 IPCC Guidelines for National Greenhouse Gas Inventories", IPCC, 2006
Link: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

4.1.1. Methodology, activity data and emission factors

The Study was conducted in accordance with the methodology developed under "2006 IPCC Guidelines". To analyze GHG production in livestock sector under the "Mitigation" and "Business-as-usual" scenarios for 2030, a complete list of livestock population relevant to Armenia was identified and their country specific and/ or default emission factors assessed. Similarly, to analyze the GHG production in land management, the complete list of crop categories and their production specificities relevant to Armenia were identified and their emission factors assessed.

Data describing agriculture sector categories and subcategories and livestock population was used for calculation of GHG emissions from enteric fermentation, manure management, biomass burning and managed soils. Specific data and calculations are additionally described under respective sectors.

Agriculture sector categories and subcategories

According to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" and based on the "2006 IPCC Guidelines", agriculture sector in Armenia includes the following categories and subcategories, which are grouped in accordance with emissions which characterize them:

3A[81] Livestock:

- **(3A1) Enteric Fermentation (CH_4)**
  - 3A1a Cattle
    - 3A1ai Dairy Cows
    - 3A1aii Other Cattle
  - 3A1b Buffalo
  - 3A1c Sheep
  - 3A1d Goats
  - 3A1f Horses
  - 3A1g Mules and Asses
  - 3A1h Swine
  - 3A1j Others (rabbits and fur bearing animals)
- **(3A2) Manure Management (CH_4 and N_2O)**
  - 3A2a Cattle
    - 3A2ai Dairy Cows
    - 3A2aii Other Cattle
  - 3A2b Buffalo
  - 3A2c Sheep
  - 3A2d Goats
  - 3A2f Horses
  - 3A2g Mules and Asses
  - 3A2h Swine
  - 3A2i Poultry
  - 3A2j Others (rabbits and fur bearing animals)
- **(3C) Aggregate sources and non-CO_2 emissions on land;**
  - 3C1 GHG (CH_4 and N_2O) emissions from biomass burning:
    - 3C1b GHG (CH_4 and N_2O) emissions from biomass burning in cropland
- **3C3 GHG (CO_2 and N_2O) emissions from urea application;**
- **3C4 Direct N_2O emissions from managed soils;**
- **3C5 Indirect N_2O emissions from managed soils;**
- **3C6 Indirect N_2O emissions from manure management**

[81] The categorization into 3A and its subcategories here and elsewhere is done in accordance with "2006 IPCC Guidelines" in order to maintain consistency with similar other reports

Livestock population

The headcount of livestock is the key indicator for estimating GHG emissions from livestock, including enteric fermentation and manure management.

Population data was extracted from official national statistics - Statistical Committee of the Republic of Armenia, with consideration of “National Greenhouse Gas Inventory Report of Armenia 1990-2017”.

The main official document that quantifies livestock headcount and agricultural production volumes by 2030 is “The Strategy”. The document explicitly specifies the headcounts of *cows, sheep and goat* (combined), and *swine* projected to be produced in 2030, as well as the corresponding volumes of main agricultural production.

For *buffalo, horses, mulls and asses, fur bearing animals and rabbits*, no population data exists in “The Strategy”. Therefore, additional sources have been used to forecast the population size of these livestock by 2030. The specifics of population calculations are presented in more detail in the “National Greenhouse Gas Inventory Report of Armenia 1990-2017” and in the “Third National Communication's National Inventory Report[82]”.

During the Study, the following documents were analyzed:

1. Data published by the Statistical Committee of the Republic of Armenia:
    - Livestock population (by category and sub-categories) as of January 1 of each year from 1991 to 2019;
    - Cattle and poultry sold for slaughter (total live-weight/ thousand tons/ annually);
    - Animals and poultry sold for slaughter-by-slaughter weight, in thousand tons, for each animal sub-category including those sold by commercial organizations and households; on monthly basis;
    - Data on the number of cattle slaughtered and lost in commercial organizations;
    - Exports and imports of domestic animals (quantity, live-weight);
    - Annual average milk production;
    - Data on the average live weight of domestic animals (kg), feed digestibility (%), growing cattle average weight gain per day (kg/day), manure dumping, and the shares of manure used for burning and as a fertilizer.
2. Historical data published by the “National Greenhouse Gas Inventory Report of Armenia 1990-2017”;
3. Professional literature on livestock activity data, including specific aspects for breeding livestock, sheep, goat, swine, rabbits, etc.[83,84,85,86].

[82] Third National Communication on Climate Change under UNFCCC, 2014.
[83] Livestock breeding, E.A. Arzumanyan, 1983
Link: https://library.anau.am/images/stories/grqer/Anasnabutsuyun/arzumanyan-anasnabutsutyun.pdf
[84] “Sheep and goat breeding”, S.A. Pambukchyan, 2019
Link: https://library.anau.am/images/stories/grqer/Anasnabutsuyun/pambuxchyan-ochxarabutsutyun.pdf
[85] “Swine breeding”, S.A. Pambukchyan, 2013
https://library.anau.am/images/stories/grqer/Anasnabutsuyun/Pambuxchyan.pdf
[86] “Rabbit breeding”, L.G.Minasyan, 1985
Link: https://library.anau.am/images/stories/grqer/Anasnabutsuyun/minasyan-Tsagar.pdf

The following activity data was used to calculate livestock annual average population by categories of species by 2030:

- Population data at the beginning of 2030;
- Meat, milk and egg production data by 2030;
- Data on population composition for each livestock;
- Data on fecundity of each livestock;
- Data on sales of meat and slaughtered animals, as most of the animal raised for meat production (calves, lambs, swine, birds, rabbits) are alive just for a limited time during the year and their number is neither reflected in the official statistics of the beginning of-the-year nor at the end of the year.

"The Strategy" forecasts 316,691 cows for year 2030. Based on the Project team expert opinion of the Study group on farm management, the number of cows must be approximately 40-45% of the herd, making the proportion of bulls and growing cattle - 55-60%. According to the latest data from SCRA[87], in 2018 cows comprised approximately 45% of the cattle population, whereas growing cattle and bull headcounts were 54% and 1%, respectively. This proportion has been considered for the calculation of cattle population size in 2030 under "Business-as-usual" scenario.

The population sizes and corresponding calculations for sheep, goat and swine by 2030 are based on the projected numbers presented in "The Strategy". Proportion of mother and offspring in the herds are calculated based on Equation 10.1 proposed in "2006 IPCC Guideline":

AAP = (Days alive) x NAPA/365

Where: AAP = annual average population

NAPA = number of animals born annually

The annual statistical data on *goats and sheep* population is presented as a combined number in "*The Strateg*y" and multiple yearbooks of SCRA. However, GHG calculation according to "National Greenhouse Gas Inventory Report of Armenia 1990-2017" considered separate numbers of these livestock with separate emission factors (EFs) and calculation tiers. As such, the dynamics of the change in goat and sheep population over time has been analyzed for the period 1991-2018, and based on that data a proportion of 25,495 goats and 980,576 sheep has been forecasted for 2030.

For the *buffalo, horses, mulls and asses, fur bearing animals and rabbits*, no population data exists in "The Strategy" and the population sizes are not reported in SCRA annual reports. Therefore, the population of these agricultural livestock was calculated based on data used for the "National Greenhouse Gas Inventory Report of Armenia 1990-2017". The corresponding population sizes were extrapolated to predict the potential populations in 2030. Since the population of *buffalo, horses, mulls and asses, fur bearing animals* comprise 0.033%; 0.005%; $2.2x10^{-9}$%; and 0.004% of entire livestock respectively, no resource and space limitation for the population increase to the projected 2030 population size was considered. These livestock are not used for meat production and therefore, under normal conditions, their annual life expectancy is considered to be equal to 365 days.

[87] Statistical Yearbook of Armenia, 2019, SCRA, Yerevan 2019.

The 2030 average number of *rabbits* has been calculated taking into account the activity data, based on the methodology provided by the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" using the Equation 10.1 proposed by "2006 IPCC Guideline".

The 2030 average number of *poultry* has been calculated taking into account the projected poultry meat and egg production volumes by "*The Strategy*", based on the methodology provided by the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" and using the Equation 10.1 proposed by "2006 IPCC Guideline".

Quality assurance/quality control and accuracy for livestock

Quality assurance/ quality control measures for the current study followed the protocol of the "National Greenhouse Gas Inventory Report of Armenia 1990-2017". Consideration of all the categories of animals managed in the country were made for assuring data completeness and accuracy. The data collection, aggregation and processing methods and approaches and their correspondence to the actual situation was also analyzed.

According to "2006 IPCC Guideline", the uncertainty associated with populations will vary widely depending on source but should not exceed the ± 20% range. The possible uncertainty of cattle population is estimated from ±8% to ±10% due to the existing deviations in data on livestock population.

Managed soils: aggregate sources and non-CO_2 emissions from land use

The use of fertilizer/urea and respective net CO_2, direct and indirect N_2O emissions from added nitrogen (N), and CH_4 emissions from biomass burning in croplands are the key indicators for estimating GHG emissions from lands.

The main official document that quantifies agricultural crop production volumes and productivity by 2030 is *"The Strategy".* The document explicitly specifies the projected production of six main agricultural crop groups, such as cereals and legumes, potato, vegetable crops, melons, fruits and berries, and grapes. The calculations of GHG emissions due to the production of these crops in 2030 are based on the projected numbers presented in *"The Strategy*".

For the technical and feed crops, no projections exist in *"The Strategy*" and the potential gross production and productivity levels for 2030 are forecasted based on the production trends observed during the period 2016-2020 as published by SCRA.

The agricultural land area used for each crop group, that is used for the evaluation of fertilizer use by 2030, is calculated taking into account the gross yield of agricultural crops and respective productivity forecasts.

Data for the period 2017-2019 published by the SCRA was used to estimate the production volumes and productivity of the same crop groups, that was subsequently used to deduce average fertilizer use per group.

The projected use of urea was calculated based on the projection of the urea use for the period 2017-2019, and extrapolation for the overall crop production and corresponding fertilizer was made for 2030.

Emissions biomass burning is based on the calculation of the agricultural area of cereals and legumes production by 2030 and is based on the projected production volumes presented in "The Strategy".

Under the "Business-as-usual scenario", land types have been established according to "National Greenhouse Gas Inventory Report of Armenia 1990-2017" and the land use categories for 2030 are taken from *"The Strategy*".

Quality assurance/quality control and accuracy for the aggregate sources and non-CO_2 emissions from land use and management

The estimates of GHG inventory in land use category have been established according to "National Greenhouse Gas Inventory Report of Armenia 1990-2017". Uncertainties are mostly due to the lack of complete and accurate information on potential changes in the management strategies and land use patterns by 2030.

4.1.2. Emissions from Agriculture sector

In the framework of this Study, GHG emission from Agriculture sector in Armenia for 2030 have been calculated under two scenarios: "Business-as-usual" and "Mitigation".

"Business-as-usual" scenario assumes that in future there will be no significant changes in internal and external factors which impact the current behavior, attitude, and priorities, nor the technology, economy or policies and existing circumstances in agricultural sector in Armenia. However, for livestock it considers potential increased population sizes and correspondingly increased meat, milk and egg production volumes by 2030. In case of GHG emissions from land use and management, projected production of main agricultural crops by 2030 is considered.

"Mitigation" scenario, to the contrary, considers intervention in the internal and external factors which impact the current behavior, patterns and priorities of current agricultural production and management in Armenia.

The "Mitigation" scenario is based on the analysis of the data from "Business-as-usual" scenario. Depending on these data, the biggest emitters are assessed and respective interventions to reduce emissions from these emitters are considered. Under the "Mitigation" scenario, international best practices of livestock and land management to reduce GHG emission are considered and their suitability for the context of Armenia is assessed. For the suitable best practices, animal population sizes, changes in land management and agricultural main practices under interventions and respective EFs are re-calculated.

4.1.3. Livestock

4.1.3.1. "Business-as-usual" scenario

Table 13 summarizes the comparison of the livestock population in 2017 and 2030 under the "Business-as-usual" scenario. As described earlier in this Report, the population of cattle, sheep and goat, and swine are taken from "*The Strategy*". The population of other livestock is calculated based on the historical statistical data (see Chapter 4.1.1). No changes in animal breeds and their diet, therefore EFs, have been considered. Emissions from enteric fermentation and manure management are presented.

Table 13: Estimated livestock population by 2030 in Armenia under the "Business-as-usual" scenario

Livestock	Headcount 2017, abs	Headcount 2030, abs	Change since 2017, %
3.A.1.a - Cattle	711,641	1,199,115	68.5
3.A.1.a.i - Dairy Cows	329,283	542,000	64.6
3.A.1.a.ii - Other Cattle			
Bulls	29,045	8,394	-71.1
Growing cattle	370,698	648,721	75.0
3.A.1.b - Buffalo	719	1,010	40.5
3.A.1.c - Sheep	909,084	1,073,628	18.1

Livestock	Headcount 2017, abs	Headcount 2030, abs	Change since 2017, %
3.A.1.d - Goats	34,666	54,981	58.6
3.A.1.f - Horses	10,340	9,616	-7.0
3.A.1.g - Mules and Asses	1,947	927	-52.4
3.A.1.h - Swine	395,243	499,192	26.3
3.A.1.h – Poultry	5,210,867	8,082,054	55.1
3.A.1.j - Other	-		
Fur bearing animals	9,534	22,024	131
Rabbits	66,662	277,982	317

Enteric fermentation

The emissions from **enteric fermentation** under the "*Business-as-usual*" scenario from *cattle* as well as from *buffalo* and *sheep* are estimated by applying Tier 2 approach using the animals' country-specific EFs based on "National Greenhouse Gas Inventory Report of Armenia 1990-2017" data. The emissions from enteric fermentation under the "Business-as-usual" for other livestock are estimated by applying Tier 1 with default EFs based on "National Greenhouse Gas Inventory Report of Armenia 1990-2017".

EF estimates using the Tier 2 method are likely to be in the order of ±20%. Therefore, uncertainty of the emission factor for the cattle is estimated at ±20%".

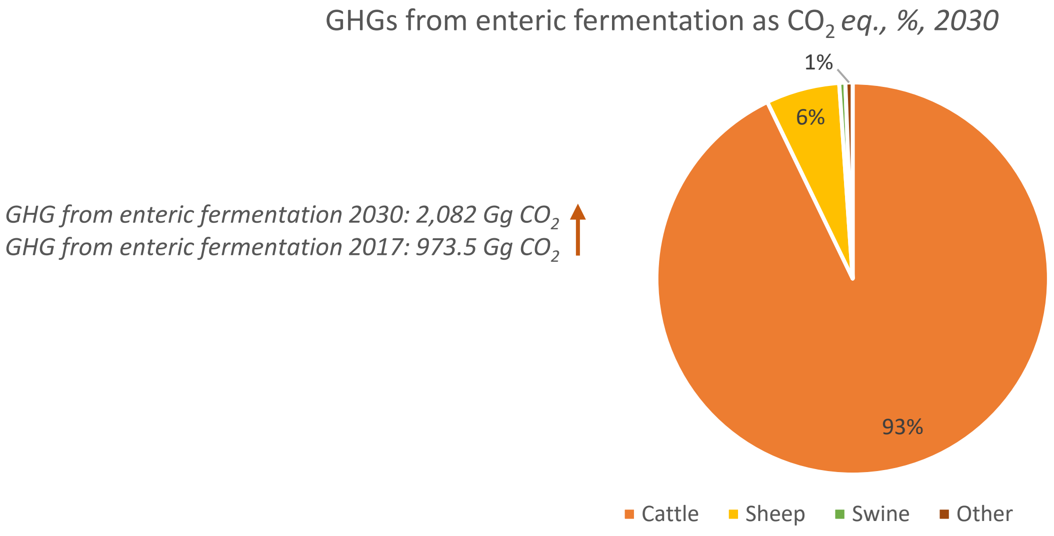
Below are the country-specific and default EFs, along with the applied Tiers used for GHG emission calculations from Enteric fermentation (Table 14).

Table 14: Country-specific and default emission factors, and the calculation Tiers used under the "Business-as-usual" scenario

Livestock	Emission factor kg CH_4/per head/per year	Tier
3.A.1.a - Cattle – *Caucasian Brown*		
3.A.1.a.i - Dairy Cows	67.7	2
3.A.1.a.ii - Other Cattle		
Bulls	89.3	2
Growing cattle	37.3	2
3.A.1.b - Buffalo	71.8	2
3.A.1.c - Sheep	5.6	2
3.A.1.d - Goats	5.0	1
3.A.1.f - Horses	18.0	1
A.1.g - Mules and Asses	10	1
3.A.1.h - Swine	1.0	1
3.A.1.j - Other		
Fur bearing animals	0.68	1
Rabbits	0.8	1

Under the "Business-as-usual" scenario, by 2030 GHG emissions from enteric fermentation in Armenia are expected to reach 2,082 Gg CO_2 eq., demonstrating a 113.9% increase as compared to GHG emissions from enteric fermentation in 2017. The largest contributor in GHG emissions from enteric fermentation is cattle, responsible for 92.8% of total GHG production from enteric fermentation, followed by sheep, accounting for 6.1% GHG production from enteric fermentation (Figure 7).

Figure 7: GHG production from enteric fermentation by dominant livestock sectors in Armenia under the "Business-as-usual" scenario by 2030



Manure management

Emissions from **manure management** under the "*Business-as-usual*" scenario are calculated in accordance with the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" for the following manure management systems used in Armenia:

1. Pasture/Range/Paddock
2. Daily spread
3. Solid storage
4. Liquid/Slurry
5. Poultry manure with litter
6. Poultry manure without litter.

Methane emissions from manure management for *cattle*, *buffalos* and *sheep* arecalculated using Tier 2 methodology according to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017 and "2006 IPCC Guidelines for National Greenhouse Gas Inventories". Methane emissions from manure management for other livestock categories are calculated using Tier 1 methodology according to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" and "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

EF estimates using the Tier 2 method are likely to result in uncertainty of ±20%. Therefore, uncertainty of the emission factor for the *cattle* is estimated ±20.

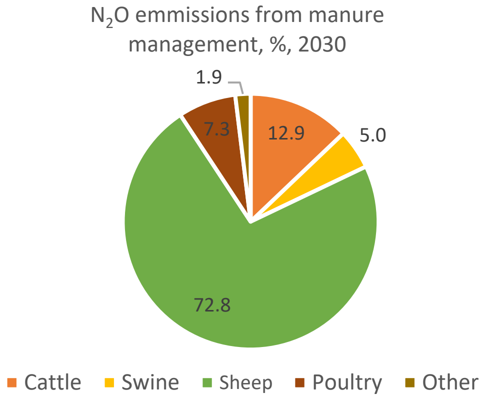
Nitrous oxide emissions from manure management of *cattle*, *buffalos* and *sheep* were calculated using Tier 2 methodology, and for other livestock categories - using Tier 1 methodology with country specific activity data and using the default emission factors per manure management system according to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017" and "2006 IPCC Guidelines for National Greenhouse Gas Inventories".

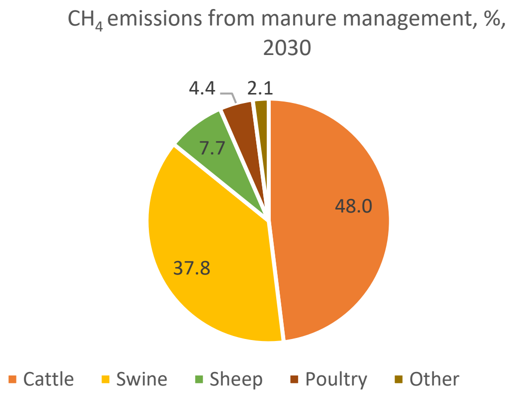
Under the "Business-as-usual" scenario, by 2030 manure management is forecasted to result in production of 2.6 Gg CH_4 and 0.24 Gg N_2O emissions (Table 15; Figure 8), equivalent to the 130 Gg CO_2. *Cattle* and *swine* are the biggest CH_4 emitters, responsible for the 48.0% and 37.8% of total CH_4 emissions, respectively. *Sheep* is the biggest N_2O emitter, responsible for the 72.8% of total N_2O emissions from manure management.

Table 15: Methane and nitrous oxide emissions from livestock manure management under "Business-as-usual" scenario by 2030

Livestock	**Emissions**	
	CH_4 (Gg)	N_2O (Gg)
3.A.2 - Manure Management	*2.644224*	*0.239761*
3.A.2.a - Cattle	1.270334	0.030913
3.A.2.a.i - Dairy cows	0.702834	0.014965
3.A.2.a.ii - Other cattle	0.567500	0.015949
3.A.2.b - Buffalo	0.001174	5.39×10^{-05}
3.A.2.c - Sheep	0.202742	0.174580
3.A.2.d - Goats	0.006048	0.004536
3.A.2.f - Horses	0.010481	4.782×10^{-05}
3.A.2.g - Mules and Asses	0.000556	2.32×10^{-06}
3.A.2.h - Swine	0.998384	0.012026
3.A.2.i - Poultry	0.117290	0.017601
3.A.2.j - Other (Rabbits, Fur bearing animals)	0.037215	0.000000

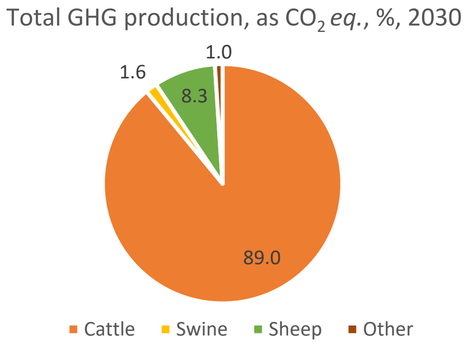
Figure 8: Methane and nitrous oxide production from enteric fermentation and manure management by dominant livestock sectors in Armenia under the "Business-as-usual" scenario by 2030





Total GHG production from enteric fermentation and manure management by 2030 in Armenia under the "Business-as-usual" scenario is estimated to amount in 2,212 Gg CO_2 eq. Cattle is the biggest emitter in terms of cumulative GHG production, responsible for 89% of GHG emission, followed by sheep with an 8.35% share of GHGs (Figure 9)

Figure 9: Total GHG production from enteric fermentation and manure management by dominant livestock sectors in Armenia under the "Business-as-usual" scenario by 2030



4.1.3.2. "Mitigation" scenario

CH_4 emissions from enteric fermentation accounted for 49.5% of emissions from Agriculture sector in Armenia in 2017, while 1.8% of CH_4 emissions came from manure management.

Cattle is responsible for 87.2%[88] of GHG emissions from enteric fermentation (in form of CH_4) in Armenia in 2017. Under the "Business-as-usual" scenario, if no mitigation actions are taken, the share of *cattle* in GHG production from enteric fermentation is forecasted to increase to 92.8% by 2030.

Cattle is responsible for 48.0% of CH_4 and 12.9% of total N_2O emissions from manure management under the "Business-as-usual" scenario. This suggests that the main mitigation actions should be directed to the c*attle* category of livestock.

The "Mitigation" scenario considers improvements in GHG production and emissions both in enteric fermentation and manure management as compared to "Business-as-usual" scenario.

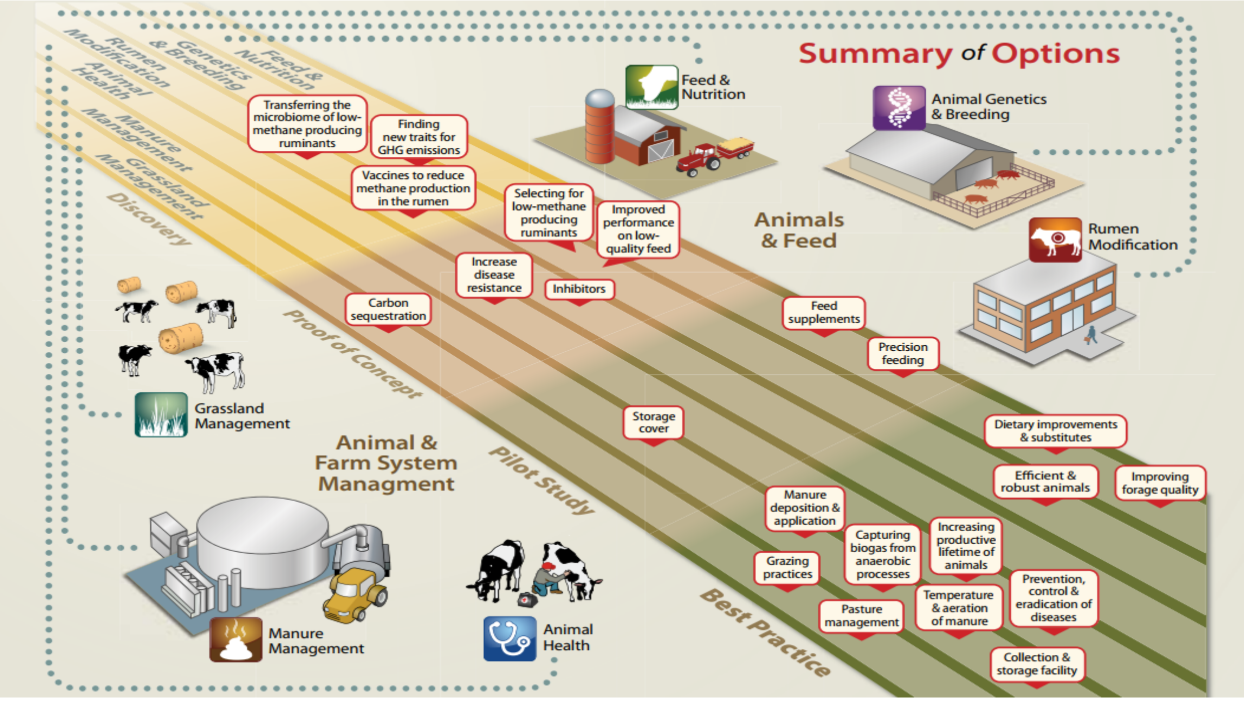
Currently, multiple approaches for reduction of enteric fermentation from *cattle* exist at different stages of development. Those initiatives can be categorized in accordance to their development stage, such as "Discovery", "Proof of concept", "Pilot studies" and "Best practices[89] as illustrated in Figure 8. For the purpose of this Study, approaches under the category of *international "best practices" are considered under the "Mitigation" scenario,* while some others have not yet proved to be effective globally.

In terms of other livestock, since no interventions are considered under the "Mitigation" scenario, the population sizes, EFs, and calculation tiers, as well as calculations uncertainties for GHG production in 2030 is the same as considered under the "Business-as-usual" scenario.

[88] National Inventory Report (NIR), CHMI, 2017

[89] "Reducing greenhouse gas emissions from livestock: Best practice and emerging options." Global Research Alliance, 2013.

Figure 10: Current approaches for reduction of GHG production from livestock



Source: Global Research Alliance on Agricultural Greenhouse Gases (GRA) and Sustainable Agriculture Initiative (SAI) Platform, 2013)

The calculations related to the *cattle* population sizes and EFs under the "Mitigation" scenario are presented in due course parallel to the introduction of mitigation actions.

Currently, there are three main "best practices" under mitigation actions for CH_4 production from cattle, namely improvement of livestock health, improvement of animal breeding and genetics, and improvement in feed quality and digestibility.

These are described in more detail under the best practice analysis section within the "EU practice and regulations to reduce GHG emissions from the Agriculture" chapter. It is important to mention, that best practices 2 and 3 are interrelated and assume optimal food quality for improved digestibility and productivity for each *cattle* breed.

Best practice 1: Livestock health is one of the main factors for ensuring food production efficiency and subsequently, food security, based on the fact that animal loses and/or lower productivity due to health matters result in higher emissions per unit of animal product. According to the data published by WOAH in OIE[90], there is less than 100 cattle deaths per year in Armenia. This suggests only a negligible current effect of livestock health on GHG production. Moreover, it is likely that either the current level of low animal mortality rates is sustained in Armenia by 2030 or improvements in this fields will result in even lower levels of mortality rate. In fact, "*The Strategy"* outlines the developmental directions in agriculture by 2030, among which the improvement of services related to the animal health and wellbeing is mentioned. Those include development of preventive measures for animal diseases, use of vaccine and establishment of modern private veterinary clinics. This will result in further reduction of livestock health impact on GHG production in Armenia in 2030. Due to the negligible share of livestock health issues in GHG production in Armenia, this mitigation approach is not further considered.

[90]World Animal Health Information System, Reports. Link: https://wahis.oie.int/#/home

Best practice 2: Breeding and genetics improvements include selection and use of animals having identified desirable traits with additional refinements to ensure that the animal is adapted to specific country environments. This measure is considered in more detail later in the Report.

Best practice 3: Adequate feeding and management strategies should be in place for realization of the full genetic potential of the animal. This measure is considered in more detail later in the Report.

Rumen ecosystem - the rumen and reticulum are the largest part in ruminant's stomach, responsible for the energy and nutrient of the animal based on micro-organisms ferment plant materials. The micro-organisms in rumen - methanogens, produce methane. Rumen modification strategies are aimed at managing the methanogens and micro-organisms in the rumen involved in methane production. However, the changes in rumen ecosystems are based purely on experimental approach. Rumen modification is yet at the stage of discovery and no effective Pilot Studies or Best practices are observable for this strategy. Although being a promising and fast developing area, it is still scientifically undiscovered and not largely used in Agriculture. Thus, application of rumen ecosystem management strategy was not considered under this Study.

Breeding and genetics improvements

Despite the existence of several approaches of achieving full genetic potential of livestock and ensuring reduced GHG production under different stages of development as presented in Figure 8, currently best practice review of the field considers mostly the introduction of more efficient and robust genetic breeds. This will also be considered for the purpose of the current Study.

Since this approach considers introduction and selection of more productive genetic breeds, the c*attle* population size calculations used in "Business-as-usual" scenario and based on "*The Strategy"* have been replaced by the *Cattle* population forecasts that consider the projected meat and milk production from the same document.

"The Strategy" defines 1,252,000 tons of milk and 115,100 tons of beef production by 2030. Achieving these production volumes with the local Caucasian Brown breeds in terms of reduction in GHG emissions is not seen as realistic, as demonstrated in "Business-as-usual" scenario.

According to the "Fourth National Communication on Climate Change[91]", Republic of Armenia considers importing 100,000 high-yielding cows to the country by 2030. To achieve the projected meat and milk production volumes by 2030, the "Mitigation" scenario considers the use of mixed population of the newly introduced Swiss breed and mixed breeds with increased productivity conditioned by breeding with the local Caucasian Brown breeds.

The Swiss breed was chosen for this purpose as it provides increased productivity without causing special deviation of beef breeding technologies, obstacles for their health, behavior and feeding. Thus, import of purebred heifers together with production of mixed breed offspring via natural cross-breeding and artificial insemination provide an opportunity to have about 100,000 purebred high-yielding cows by 2030 and 179,770 mixed-bred c*attle*.

This *cattle* population will allow to achieve the meat and milk production volumes projected for 2030, while simultaneously reducing the *cattle* population in the country (See Annex 1 for animal activity data). (The specifics of animal import, insemination, etc. is presented under chapter "Cost and feasibility study of the mitigation scenario for livestock management").

[91] Fourth National Communication on Climate Change under UNFCCC, 2020.

Overall, by applying breeding and genetic improvement approach, the *cattle* population forecast for 2030 in Armenia can be achieved with the distribution presented in Table 16.

Table 16: Estimated livestock population by 2030 in Armenia under the "Mitigation" scenario

Livestock	Headcount 2030, abs	Change since 2017, %	Difference from 2030 "Business-as-usual" scenario, %
3.A.1.a – Cattle -total	**279,770**	-15.0	-48.4
3.A.1.a.i - Dairy Cows -*Swiss pure breed*	100,000	-	
3.A.1.a.i - Dairy Cows -*crossbreed*	179,770	-	
3.A.1.a.ii - Other Cattle			
Bulls-total	4,219	-85.5	-50.1
Bulls- *Swiss pure breed*	2,222		
Bulls- *Mix breed*	1,997		
Growing cattle -total	**337,721**	-8.9	-47.9
Growing cattle- *Swiss purebred*	120,000		
Growing cattle- *crossbreed*	217,721		

Feeding regime

As stated above, optimal feeding regime should be used for each breed type to achieve the maximum level of productivity, since low-quality and low-digestibility feeds result in relatively high enteric emissions per unit of meat or milk. Better grassland management, improved pasture species, changing forage mix and greater use of feed supplements to achieve a balanced diet, including cropping by-products and processing of crop residue can increase animal productivity and lower emissions per unit of product. Yet, it is important to consider the entire life cycle of production of supplementary feeds and/or processing so that these will not outweigh any on-farm reduction of GHG emissions.

Currently, animal feed and forage management practices system are underdeveloped in Armenia. Most of the livestock owners use outdated technologies for animal feeding. There is lack of feed production and management capacities. Farmers lack progressive knowledge on methods of growing and harvesting feed crops, properly storing the feed and feeding itself. The properly designed feed ratios are not applied by the farmers due to lack of knowledge about forming proper ratios for different age groups of animals. Besides, farmers usually do not grow high value feed crops due to lack of knowledge, financial resources, limited land areas and irrigated land, machinery, etc. The mentioned activities result in losses of feed nutrient value. For example, farmers need special machinery to be able to grow corn during the vegetation period, harvest it, produce corn silage and store it. Another example is the more effective and efficient use of pasture and grazing[92].

As part of the "Mitigation" scenario, in order to improve the food and forage practices applied in Armenia, optimal diets for increased animal health and productivity for both Swiss pure-bred animals (Table 17) and mixed breeds (Table 18) have been analyzed and suggested in this Report based on Project expert knowledge. These diets take into account the energetic and nutritional requirements of *Cattle* for optimal meat and milk production.

[92] Investor Roadmap for Dairy Value Chain, FAO, 2019.

Table 17: Estimated Feeding regime for Swiss pure-bred cattle

Feed portion	
In farm keeping (wintering) period / 210 days	
Rough feed / 5 feed units	• Grass – 11kg (5km)
Juicy (wet) feed / 3.1 feed units	• Corn silage – 15kg (3km) • Fodder beet – 8kg (1km)
Combined feed / 5 feed units	• Combined feed – 5kg (5km)
Pasturing period / 155 days	
Pasture green / 11 feed units	• Pasture green – 48 kg (11km)
Combined feed / 3 feed units	• Combined feed – 3kg (3km)
Total 14km / daily	

Table 18: Estimated Feeding regime for mixed breed cattle

Feed portion	
In farm keeping (wintering) period / 210 days	
Rough feed / 4.5 feed units	• Grass – 10kg (4.5km)
Juicy (wet) feed / 3.5 feed units	• Corn silage – 12kg (2.5km) • Fodder beet – 8kg (1km)
Combined feed / 3.5 feed units	• Combined feed – 3.5kg (3.5km)
Pasturing period / 155 days	
Pasture green / 11 feed units	• Pasture green – 48 kg (11km)
Combined feed / 3 feed units	• Combined feed – 3kg (3km)
Total 11.5 km / daily	

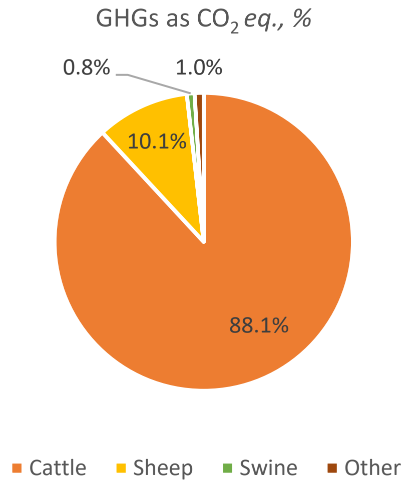
The country specific EFs generally depend on animal activity data, including their feed and forage quality, heard management, etc. Therefore, country specific EFs have been calculated for Swiss pure breed and mixed cross-breed cattle considered under the Best practices 2 and 3 - **Animal breeding and genetics and improving feed quality and digestibility** - for "Mitigation" scenario (Table 19). Activity data for the calculation of the methane emission factor from enteric fermentation for Swiss pure breed animals and crossbreeds are presented in Appendix 1.

Table 19: Country-specific emission factors, and the calculation Tiers used under the "Mitigation" scenario

Livestock	**Emission Factor** **kg CH_4/per head/per year**	**Tier**
3.A.1.a – Cattle		
3.A.1.a.i - Dairy Cows -*Swiss purebred*	125.7	2
3.A.1.a.i - Dairy Cows -*Mix breed*	92.8	2
3.A.1.a.ii - Other Cattle		
Bulls- *Swiss purebred*	109.2	2
Bulls- *Mix breed*	92.3	2
Growing cattle- *Swiss purebred*	53.0	2
Growing cattle- *Mix breed*	38.3	2

Under the "Mitigation" scenario, the changes in reared Cattle breeds with increased meat and milk production capacities result in relatively lower animal population size. Under the "Mitigation" scenario, considering a combined use of best practices 2 and 3 - use of improved animal breeds and feed quality and digestibility - the estimated GHG production from enteric fermentation by 2030 is forecasted at 1,254 Gg CO_2 eq. In this case, like in "Business-as-usual" scenario, cattle are the biggest emitter, responsible for 88.1% of total GHG production in enteric fermentation followed by sheep, responsible for 10.1% (Figure 11). The rest of livestock contribute to only 1.8% GHG productions in enteric fermentation in the country by 2030 (Figure 7).

Figure 11: GHG production from enteric fermentation by dominant livestock sectors in Armenia under the "Mitigation" scenario by 2030



4.1.4. Manure management

There are several best practices for the reduction of GHG production from manure management, including:

- improved collection and storage of manure including maintenance of optimal temperature and aeration;
- improvement of manure deposition and application to soils;
- Anaerobic digestion with biogas production and capturing.

Animal housing systems with concrete or hard clay floors and use of feedlots allow not only prevention of run-off and eutrophication of the environment, but also improve collection of manure and urine. Management options that regulate temperature and aeration of solid and liquid manure can substantially decrease CH_4 and N_2O emissions, with a variety of approaches available for different systems. In fact, the establishment and operation of smart animal farms are in the focus of Government Decree N269-L of RA (2019), "On Approval of the State Assistance Program for the Construction or Reconstruction of Small and Medium-Sized "Smart" Livestock Barns and Their Technological Provision"[93], that offers government support for installation of small and medium sized smart animal farms in Armenia.

Three main models of smart farms depend on livestock population size and include farms with livestock population of 10-15 heads, 20-25 heads and 40-45 heads. The smart farms contain air conditioners for the aeration and temperature control in the animal housing, rubber covers for the ground, cooling system (only for the farms with 40-45 livestock), and indoor manure collection units (only for the farms with 20-25 and 40-45 livestock).

AD is a process where degradation of organic fraction of manure by a consortium of anaerobic microorganism produce a gas, mainly composed of CH_4 and CO_2, called biogas. The biogas can then be captured to be used as a fuel or energy source. This process allows prevention of CH_4 emissions to atmosphere, and, after the biogas is burned, it is converted to CO_2. This, on average, has 29 times less Global Warming Potential.

[93]RA Government decision N 369-L to approve the state support program for small and medium "smart" livestock construction or reconstruction and technological support, RA Government, April 4, 2019 http://www.irtek.am/views/act.aspx?aid=99082&fbclid=IwAR3epAsPObqU5I6B0jnDvY18KRiBnQX235g4ZiRglfXjnQxecbyVFOw_Ek

Additionally, depending on processing conditions, leftover solid and liquid fractions from AD can be further stabilized and are more acceptable and safer for use as a fertilizer or feed supplement.

AD is a well-established method for *cattle* manure management and as such is widely used as a best practice for manure management worldwide. In contrary, manure from other livestock, such as *goats, sheep, swine*, is not easily manageable in AD process due to some intrinsic characteristics, such as high content of lignocellulose, high acidity of the manure, unfavorable C:N ratios, etc. Therefore, AD is not widely used for these categories. Pre-treatment of these wastes for AD, although possible, generates and emits high level of GHGs, such as nitrous oxide, and therefore cannot be considered for the mitigation of climate change.

The same is true for *Poultry* manure. Despite the high volume of manure produced in *Poultry* operations worldwide, AD and biogas production from this waste is challenging due to a strong inhibition of AD process by high concentrations of ammonia. High ammonia level in the waste negatively impacts methanogenic bacterial activity and thereby the entire biogas production process, reducing the biogas yield and its quality. A number of experimental approaches exist that address problem of an elevated ammonia concentration by supplementary addition of inorganic sorbents or different additives exhibiting ion-exchange capacity, etc. Nevertheless, unfavorable economic and other issues associated with operational feasibility, and low biogas yield from poultry [94].

Therefore, currently introduction of AD manure management is considered only for *cattle*. The success of AD process, among other factors, depends on the feedstock quantity, hence livestock population in the farm to assure the economic viability of the operation. As a cutoff, AD was considered for the farms that house more than 11 cows.

According to Agricultural Census of Armenia 2014[95], 76% of the cattle is in the farms which house less than 10 cows (designated as Small farms). Since "*The Strategy*" suggests increased animal farm sizes by 2030, we have made the following assumption for manure management under the "Mitigation" scenario:

1. By 2030 55% of c*attle* will be reared in Small farms and 45% in Large farms (more than 11 cows).
2. The *cattle* population in Large farms will include 75% of Swiss pure breed c*attle* and 25% of crossbreed *cattle*. The rest of *cattle* will be distributed in Small farms.
3. In the Large farms, 79% of manure will be directed to AD, and the rest will be managed under the Pasture/Range/Paddock category.
4. In the Small farms 47% manure that is produced by farms with more than 11 heads of cattle (according to the calculations of economic viability of AD process) will directed to AD, and the rest will be managed according to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017".
5. No difference in activity data and manure management strategies are assumed for other categories of livestock as compared to the "Business-as-usual" scenario (for details refer to the National Greenhouse Gas Inventory Report of Armenia 1990-2017).

Under the "Mitigation" scenario, 2.1 Gg CH_4 and 0.22 Gg N_2O are forecasted to be produced from manure management, equivalent to the 110 Gg CO_2. Swine and cattle are the biggest CH_4 emitters, responsible respectively for 48.7% and 33.0% of total CH_4 emissions from manure management. Sheep and poultry are the biggest N_2O emitters, responsible respectively for the 80.5% and 8.11 % of total N_2O emissions from manure management.

[94] Poultry waste management in developing countries, FAO, 2013.
[95] https://www.armstat.am/en/?nid=82&id=1860

Total GHG production from enteric fermentation and manure management by 2030 in Armenia under the "Mitigation" scenario was estimated to amount to 1,364 Gg CO_2 eq. In terms of cumulative GHG emissions, cattle and sheep are the biggest emitters from manure management, responsible for the 82.2% and 13.5% of total CO_2 eq. emissions, respectively (Figure 13).

Table 20: Methane and nitrous oxide emissions from livestock manure management under the "Mitigation" scenario

Livestock	**Emissions**	
	CH_4 (Gg)	N_2O (Gg)
3.A.2 - Manure Management	*2.050396*	*0.216920*
3.A.2.a - Cattle (Swiss purebred and Mix-breed)	0.676506	0.008072
3.A.2.a.i - Dairy cows (Swiss purebred and Mix-breed)	0.419925	0.004832
3.A.2.a.ii - Other cattle (Swiss purebred and Mix-breed)	0.256581	0.003240
3.A.2.b - Buffalo	0.001174	5.388×10^{-05}
3.A.2.c - Sheep	0.2027420	0.174580
3.A.2.d - Goats	0.0060479	0.004536
3.A.2.f - Horses	0.0104814	4.782×10^{-05}
3.A.2.g - Mules and Asses	0.0005562	2.32×10^{-06}
3.A.2.h - Swine	0.998384	0.012026
3.A.2.i - Poultry	0.117290	0.017601
3.A.2.j - Other (Rabbits, Fur bearing animals)	0.037215	0.000000

Figure 12: Methane and nitrous oxide production from enteric fermentation and manure management by dominant livestock sectors in Armenia under the "Mitigation" scenario

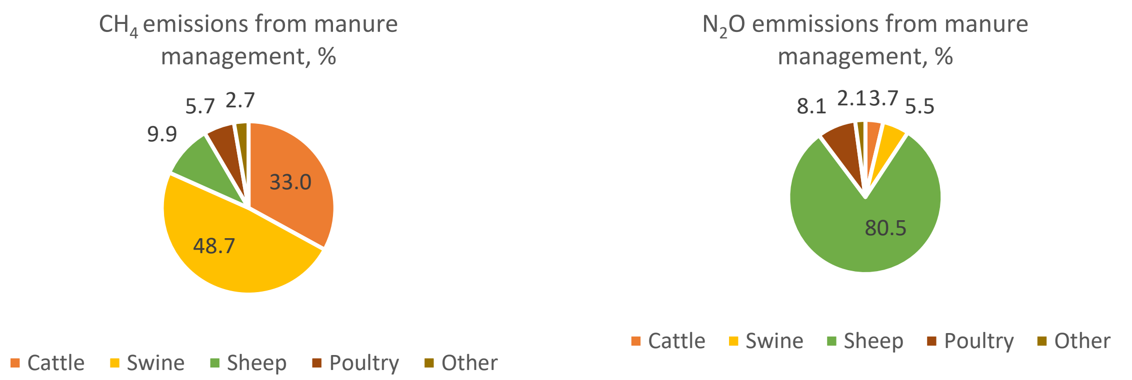
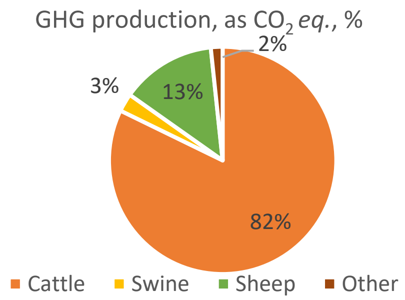


Figure 13: GHG production from dominant livestock sectors in Armenia under the "Mitigation" scenario



4.1.5. Cost and feasibility study of the mitigation scenario for livestock managements

Country level analysis: importing new breed type and considering fodder

Inputs for comparative analysis of profitability

Cost and feasibility analysis was conducted to reveal the cost efficiency of "Mitigation scenario" as described in the prior section, which suggests improving the breed of the cattle through importing Swiss breed and artificial insemination of local Caucasian Brown breed. As suggested in the scenario analysis, the number of Swiss cows in Armenia are forecasted to reach 100 thousand heads by 2030. This will be achieved by importing 2,300 cows each year, and later also through artificial insemination.

In order to assess the feasibility of "Mitigation scenario" and to further calculate cumulative cash flows and profitability indicators received as a result of this scenario application, which will allow to assess the cost efficiency for each breed, the following data was gathered:

- **The amount of produced milk per day:**

  Cross breed- 12.8 liters per cow

  Pure Swiss breed- 18 liters per cow

- **The number of days of pasturing and feedlot in each year**:

  Pasturing period during the year - 155 days

  Feedlot period during the year - 210 days

  The number of days of pasturing and feedlot in each year is the same for two breeds.

- **Other costs** (utility, transportation, maintenance, etc.) are estimated at 30% of the total cost.

The calculations were done for Swiss pure breed and crossbreed by taking into account the optimal ratio of self-made fodder and purchased fodder for both cases. Since most of the farmers use both self-made and purchased fodders for cows, expert judgment was applied to derive the optimal ratio which mostly represents the practices available on market. Table 21 and Table 22 demonstrate the estimated total cost for self-made and purchased fodder, which amount to around 491,700 AMD and 386,100 AMD correspondingly.

Table 21: Preferable feed ratio, self-produced feed and purchased feed for Swiss pure-breed

Swiss pure breed- feed portion for the desirable proportion of self-produced and purchased feed type				
In farm keeping (wintering) period 210 days	***Price, AMD***	***unit/kg***	***days***	***cost AMD***
Rough feed- grass- self-produced	25	11	210	57,750
Juicy (wet) feed - silage self-produced	25	15	210	78,750
Juicy (wet) feed - fodder beet purchased	25	8	210	42,000
Combined feed – purchased	180	5	210	189,000
Pasturing period 155 days	***Price, AMD***	***unit/kg***	***days***	***cost AMD***
Pasture green – cost per 1 cow per day	261		155	40,500[96]
Combined feed - purchased	180	3	155	83,700
Total				**491,700**

[96] The cost amounts to 40,455 AMD and is rounded upwards to 40,500 AMD for simplification purposes

Table 22: Preferable feed ratio, self-produced feed and purchased feed for Swiss mixed breed

Swiss crossbreed - feed portion for the desirable proportion of self-produced and purchased feed type				
In farm keeping (wintering) period 210 days	***Price, AMD***	***unit/kg***	***days***	***cost AMD***
Rough feed- grass- self-produced	25	10	210	52,500
Juicy (wet) feed - silage self-produced	25	12	210	63,000
Juicy (wet) feed - fodder beet purchased	25	8	210	42,000
Combined feed - purchased	180	3.5	210	132,300
Pasturing period 155 days	***Price, AMD***	***unit/kg***	***days***	***cost AMD***
Pasture green – cost per 1 cow per day	261		155	40,500[97]
Combined feed - purchased	180	2	155	55,800
Total				**386,100**

Annually 2,300 heads of pure Swiss need to be imported, the economic use of which is 7 years. The import cost of one cow is estimated at 2,400 EUR (the CBA conversion rate of 1 EUR = 640 AMD[98] was applied as of 01.01.2021).

Table 23: Swiss crossbreed

Swiss crossbreed										
Years	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Caucasian brown (old)	251,716	251,716	222,265	188,724	151,923	112,262	70,176	26,123	-	-
Swiss crossbreed	-	-	23,158	49,336	77,805	108,277	140,439	173,961	189,080	177,735
Total	**251,716**	**251,716**	**245,423**	**238,060**	**229,728**	**220,539**	**210,615**	**200,084**	**189,080**	**177,735**

Table 24: Swiss pure breed

Swiss pure breed										
Years	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Cows/headcount	2,300	4,600	8,050	12,650	18,975	27,600	39,388	53,188	72,881	99,475
The number of reproductive calves to give birth in 2 years' time	1,150	2,300	4,025	6,325	9,488	13,800	19,694	26,594	36,441	49,738

Only 20% of the cows in Armenia are estimated to be artificially inseminated by 2020. The indicator of artificial insemination is planned to increase up to 50% by year 2030, which is planned to be achieved by an annual steady 3% growth rate in artificial insemination. As a result, in 2021, only 23% of the existing 251,716 cows will be artificially inseminated with purebred Swiss semen (the cost of the semen and service is estimated at an average market price of 12,000 AMD). The average reproduction level of the population is considered to be at the level of 80%. For the purpose of this Study, it is assumed that the distribution among bulls and cows is 50% each. In 2022 the indicator of artificial insemination will grow to 26%, 2023 - 29% and 2030 - 50% respectively.

[97] Ibid
[98] https://www.cba.am/AM/SitePages/ExchangeArchive.aspx?DateFrom=2021-01-01&DateTo=2021-03-05&ISOCodes=EUR

It is also envisaged that starting from year 2023, in addition to replenishing the reproductive cows with female Swiss crossbreed calves born in 2021, the number of low productive cows in the herd will be increased from 2.5% to 6% (by 2030). As a result, starting from 2028, the reproductive cows will almost totally comprise of Swiss mixed breeds and thus the number of Swiss mixed breed will reach 177,735 by 2030.

Based on the data gathered and presented above, the cumulative cash flow and profitability indicators were assessed for livestock economy sector in cases of Swiss pure breed and mixed breed.

Table 25: Annual headcount of Caucasian Brown breed to be artificially inseminated

Years	crossbreed, head	% of artificial insemination, %	Total crossbreed to be inseminated, head
2021	251,716	23	57,895
2022	251,716	26	65,446
2023	245,423	29	71,173
2024	238,060	32	76,179
2025	229,728	35	80,405
2026	220,539	38	83,805
2027	210,615	41	86,352
2028	200,084	44	88,037
2029	189,080	47	88,867
2030	177,735	50	88,867

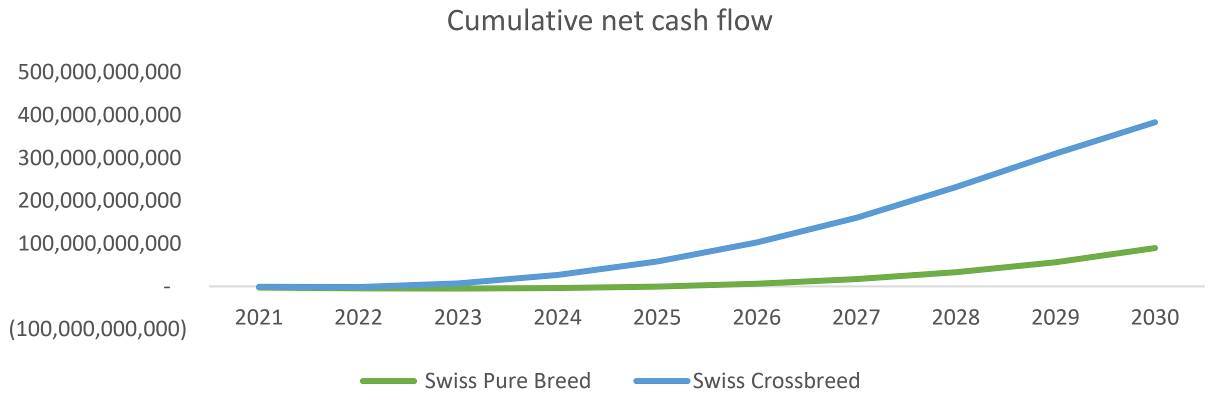
Cumulative Cash Flow

Table 26: Cumulative cash flow indicators for Swiss pure breed and crossbreed, AMD

Years	Swiss pure breed	Swiss crossbreed
2021	-2,788,799	-694,794
2022	-4,833,598	-1,480,213
2023	-5,762,395	5,865,052
2024	-5,203,191	23,382,174
2025	-2,597,986	51,484,226
2026	2,797,223	90,929,279
2027	12,005,435	142,359,012
2028	25,677,652	206,291,847
2029	45,720,374	275,862,937
2030	74,365,605	341,195,696

As illustrated in Figure 14, the break-even point in cumulative cash flow for the Swiss pure breed is forecasted to be reached in 2026, while in case of crossbreed it starts from year 2023.

Figure 14: The break-even points for importing Swiss purebred and crossbreed in the framework of the suggested scenario, billion AMD



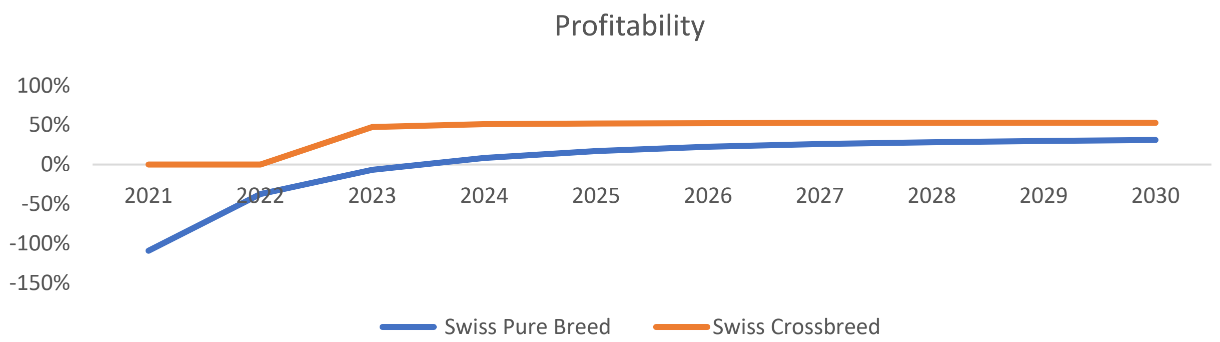
Profitability

From the profitability perspective, Swiss pure breed allows to gain profit from year 2024. In case of the crossbreed, however, as calves start to give milk or become reproductive after 2 years, the profitability starts from the third year.

Table 27: Profitability of Swiss pure breed and Swiss mixed breed

Years	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Swiss purebred, %	-113	-42	-11	4	13	18	22	24	26	27
Swiss crossbreed, %	0.0	0.0	41.7	45.5	46.3	46.7	46.9	47.1	47.1	47.1

Figure 15: Profitability calculation for application of "Mitigation scenario" in Armenia



As a result, based on the assessment from the economic stand point, the increase of the quality of livestock in a combination of importing new breeds and use of artificial insemination, proves to be economically beneficial and thus the mitigation scenario is deemed to be feasible. In fact, as a result of implementing the "Mitigation scenario" the following outcomes are expected by 2030:

- total emissions will increase by 28% (in contrast to 91.8% in case of "Business-as-usual");
- the headcount of livestock will be in accordance with "The Strategy" at level of 177,735;
- milk production will increase by 171% compared to 2017,
- beef production will increase by 213%, increase in lamb production by 167% and increase in pork production by 182%.

Farm level analysis: importing new breed type and considering fodder

As a first step we assess whether it is beneficial to improve the breed type in Armenia and calculate the feasibility at the country level. In this assessment of cost-effectiveness, we detail down the analysis on a farm level and assess whether or not a small farm holder can benefit from such an investment in a new breed and become self-efficient.

For the purposes of this analysis, small to medium sized farms are considered. In case of small farms, we consider farm capacity of 3 cows, whereas in case of a medium farm, we consider farm capacity of 13 (the 2 calves are not considered during the analysis of emissions, however they are important for the calculation of cost-effectiveness) animals, including 1 Swiss pure breed cow, 6 cross breed cows, 1 Swiss calf and 5 cross breed calves.

On *Farm level,* the breed type improvement and increase in headcount is not considered in the cost effectiveness analysis. Any calf is sold upon losing productivity/viability, which is usually after 8 years. (Income from beef sales is included in the calculation). This is done to ensure that the farmer has a steady income. Thus, during the period 2027-2028, 8-year-old cows will be sold for beef production. 6 calves (50/50 ratio of bull vs. cow) will be retained in the farm for the purpose of reproduction. Those calves will mature in three years.

In 2027, 3 of the cross-breed cows will be sold, and the remaining 2 with 1 Swiss pure breed calf will be retained for breeding. These calves will mature in 2029. The remaining 3 cows will be sold for beef products in 2029. In the same way, in 2028 another 3 calves will be retained, which will mature in 2030 and so on.

The selling price for 1 calf is usually equal to the price of 250 liters of milk. This refers to the Caucasian breed. In case of Swiss crossbreed, the breed type is improved and a better quality and higher value fodder is provided, and so the price of a calf is considered to be higher. In the calculation, the price for 1 kg of the meat of a cow is estimated at 2,000 AMD. The slaughter output is at 55%, 580 kg in case of Swiss purebred and 490 kg in case of crossbreed live weight respectively.

Additionally, maintaining expenses for 6 calves are considered for the period of 2 years until they mature (2027 and 2028). The income during those years is generated from the sales of calves, from the milk of 6 cows (1 Swiss pure breed and 5 Swiss crossbreed), and from the beef products produced from those 6 cows. The total revenue generated from mentioned agriproducts by 2030 totals to 55,122,500 AMD.

The results of the analysis, including the calculation of the net profit or loss and cumulative cash flow are presented in a Table 28. In 2021, when a farm holder does the investment for pure breed cow purchase, in the end of the year he/she still stays with certain amount of profit equaling to 260,664 AMD. During the period from 2022 until 2026, the farm holder generates steady income which is higher. This is due to additional sales of milk and calves. Starting from year 2027, the farmer keeps some of the calves for reproduction purposes, since the existing bulls and cows reach their maximum level of productivity and the cattle needs to be supplemented by growing calves. Additional feeding costs for those calves should be considered at this point. As a result, the profitability falls during these years. Moreover, in year 2027, there is a loss, as the expenses of calves’ fodder is included in the calculations and old cows that were milked were going to be sold as beef product. Nevertheless, the cumulative net cash flow calculations indicate no negative results. This means the investment of the farmer into a new breed type is beneficial in any way.

Table 28: Analysis of cost-effectiveness for importing Swiss breed cows and improving the breed type through artificial insemination and crossbreeding, 2021-2030[99]

QUANTITATIVE ANALYSIS	2021	2025	2030	TOTAL
Purchase of Swiss pure breed -1*2,400 EUR	1,536,000			1,536,000
Number of Cows - Swiss	1	1	1	1
SUBTOTAL VARIABLE FEEDING COSTS-SWISS COW	491,700	491,700	491,700	4,917,000
Number of Cows - Cross Breed	5	5	5	5
SUBTOTAL VARIABLE FEEDING COSTS-MIXED COWS	1,930,500	1,930,500	1,930,500	19,305,000
Number of - Swiss calves	0			0
SUBTOTAL VARIABLE FEEDING COSTS-SWISS CALVE	-	-	-	437,745
Number of mixed breed calves			0	0
SUBTOTAL VARIABLE FEEDING COSTS-MIXED CALVES	-	-	-	1,992,900
TOTAL VARIABLE FEEDING COSTS	2,422,200	2,422,200	2,422,200	26,652,645
OTHER VARIABLE COSTS	1,038,086	1,038,086	1,038,086	11,422,562
TOTAL COSTS	4,996,286	3,460,286	3,460,286	39,611,206
REVENUES				
Sales of milk 18 liters daily/ 195 AMD per 1 liter/ Swiss breed	1,070,550	1,070,550	1,070,550	10,705,500
Sales of milk 12.8 liters daily/ 195AMD per 1 liter/ Mixed breed	3,806,400	3,806,400	3,806,400	38,064,000
Sales of calves 1 Swiss-80,000 AMD, 1mixed breed-50,000 AMD	380,000	330,000	330,000	3,020,000
Sales of cows 1 Swiss-638,000 AMD, 1mixed breed-539,000 AMD			2,695,000	3,333,000
TOTAL REVENUES	5,256,950	5,206,950	7,901,950	55,122,500
NET PROFIT OR LOSS	260,664	1,746,664	4,441,664	15,511,294
CUMULATIVE NET CASH FLOW	260,664	7,247,321	15,511,294	

Introduction of a biogas generating system

One of the solutions to climate change mitigation caused by manure management is considered to be the use of biogas technologies. It is renewable and clean, also considered to be cheap. Biogas is used for the heating, cooking and for other utility supplies. Therefore, the biogas technologies support to sustainable development. Biogas is produced from animal waste and is also known to produce a residue a high fertilizer value for crop production. In developed countries, the use of biogas technologies (reduces the GHG emissions from manure and produces renewable energy) is supported by the government and it assures the economic and environmental regulations which create favorable conditions for the execution of mitigation activities. Meanwhile, in developing countries those conditions are also supported by the UN agencies, such UN Environmental Fund, UN Office for Disaster Risk Reduction,[100] The Green Climate fund,[101] The Climate Change Fund (CCF)[102] and other international organizations. It is used for large scale farms for production of power and heat. The use of biogas technologies not only reduce GHG emission, but also generate profit for the farmer.

[99] Please see the full table with detailed calculations for each year from 2021 to 2030 in Annex 3: Analysis of cost-effectiveness for importing Swiss breed cows and improving the breed type through artificial insemination and crossbreeding, 2021-2030

[100] https://research.un.org/en/climate-change/un

[101] https://www.greenclimate.fund/

[102] https://www.adb.org/what-we-do/funds/climate-change-fund

The process of biogas production usually takes 26 days, during which fermentation processes occur at a temperature of 35 ± 2 degrees. As a result, biogas is produced with 60-65% share of methane (the share of methane in natural gas is 80-90%).

According to the Scenario, the plant consists of the following:

1. Raw material unit
2. Reactor
3. Heating system
4. Temporary storage for biogas
5. Biogas filtration unit

Manure and drainage are poured into a receiving tank, which is equipped with a mixer. As a result of mixing, the biomass becomes completely homogeneous, after which it is pumped to the feed pool, where it is brought to the appropriate temperature, and then pumped to the fermentation tank. The fermentation tank is equipped with a central mixer, which ensures the homogeneity of the biomass during production and does not allow it to flake. The heating system ensures a steady biomass temperature to obtain a high GVA. When there is a new filling into the fermentation tank, respective volume of biomass is automatically removed from the tank and can be separated. It is possible to obtain liquid-dry biohumus separately. The biogas generated during fermentation also contains other substances, gases, which are partially purified by filtration and drainage. The result is a gas containing carbon dioxide.

The input data for biogas cost-effectiveness calculations was provided by Adaco LLC[103]. This company is the first and still the only one in Armenian market to provide possible alternative energy technologies. One of the current projects of the company is the instalment of biogas station in one of the Armenian communities, which has 5m^3 capacity. The cost of such a station is estimated at around 2,560,000 AMD.

Biogas reactor cost-effectiveness analysis were done for small (3 headcount or 120 kg/day manure) and medium (13 headcounts or 308 kg/day manure) size farms and the following input data were collected:

- Biogas produced from 1m^3
- Fertilizer produced
- Biogas price for 1 m^3
- Fertilizer price for 1 kg

Biogas generating system for a small farm with cattle headcount of 3

As a first step, the calculations are done for a farm with 3 cows. 3 cows are estimated to generate 120 kg manure per day. This is the minimum amount of manure to be processed by biogas generating system. Under this level, biogas generating system is considered not economic.

It is important to mention, that besides biogas production the farm should also have an organic fertilizer. It will be used in the farm for internal consumption or in case of a surplus, can be sold in the market for ~100 AMD per kg. The price for 1 m^3 biogas is ~100 AMD. In contrast, currently in Armenia the cost of 1 m^3 of gas is 136 AMD, which is also considered for cost-effectiveness calculations.

[103] Artak Adamyan, co-founder and director of engineering of Adaco LLC. Several meetings were conducted with Artak Adamyan in the period of 22-28.03.2021, which allowed to collect necessary information and data related to biogas reactor expenses, costs and maintenance.

The analysis considers savings for utility costs after shifting to biogas use, the payback period for the biogas station instalment (which is only cost-effective in case if the produced fertilizer is sold) and the net present value of the project calculated based on discount rates of 5% and 10%.[104]

Table 29: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 3 cows or manure production of 120 kg (calculated with fertilizers), 2021-2030[105]

QUANTITATIVE ANALYSIS	2021	2022	2025	2030	TOTAL
Biogas reactor purchase, 4,000 EUR	(2,560,000)				(2,560,000)
Maintenance Cost per year 90 EUR		(57,600)	(57,600)	(57,600)	(518,400)
TOTAL COSTS	(2,560,000)	(57,600)	(57,600)	(57,600)	(3,078,400)
Income from biogas 1 m3=100 AMD		306,372	306,372	306,372	2,757,347
Income from fertilizer 1kg=100 AMD		413,602	413,602	413,602	3,722,418
TOTAL REVENUE	-	719,974	719,974	719,974	6,479,765
Utility cost savings		95,040	95,040	95,040	855,360
TOTAL COST SAVINGS	-	95,040	95,040	95,040	855,360
TOTAL BENEFITS	-	815,014	815,014	815,014	7,335,125
NET PROFIT OR LOSS	(2,560,000)	757,414	757,414	757,414	4,256,725
NPV at 10%	**(2,560,000)**	**688,558**	**517,324**	**321,217**	**1,801,965**
NPV at 5%	**(2,560,000)**	**721,347**	**623,126**	**488,236**	**2,823,563**

The results of the analysis show, that the payback period for installment of a biogas generating system is 3.5 years and the NPV is positive with discount rates of 5% at level of 2,823,600 and at 10% at level 1,802,000. This proves, that a farm which produces 120 kg manure production per day can invest in this project.

Biogas generating system for a small farm with cattle headcount of 13

In the framework of the mitigation scenario identified during the Study, a medium farm size with a headcount of 13 cattle is considered. The headcount includes pure Swiss breed type, cross breed type and calves. The level of manure production for this headcount is estimated at level of 308 kg manure per day. Same calculations were done for biogas cost-effectiveness calculations for a farm with 13 headcounts. In this case, the payback period is 4 years. For net present value calculations, two discount rates of 5% and 10% are applied. Both discount rates result in positive net present value: 4,902,000 and 3,302,000 AMD, respectively. This means, that for a farm with 13 cattle headcount and manure production of 308 kg per day, investment in biogas generating system is profitable.

[104] The NPV is a method to determine the feasibility of investment in a project. It equals the present value of the project's net cash inflows minus the initial investment outlay. The present value of net cash flows is determined at a discount rate, which is derived considering the cost of borrowing for similar projects. Currently, there are different loans for agriculture at 5%-6% and 10%. The minimum and maximum interest rates were applied, to analyze at what borrowing rate the NPV will be positive and the project is profitable.

[105] Please see the full table with detailed calculations for each year from 2021 to 2030 in Annex 4: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 3 or manure production of 120 kg (calculated with fertilizers), 2021-2030.

Table 30: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 13 or manure production of 308 kg (calculated with fertilizers), 2021-2030[106]

QUANTITATIVE ANALYSIS	2021	2022	2023	2024	2025	2030	TOTAL
Purchase of biogas reactor, 2*4,000 EUR				(5,120,000)			(5,120,000)
Maintenance cost, 90 EUR				(57,600)	(57,600)	(57,600)	(403,200)
TOTAL COSTS	-	-	-	(5,177,600)	(57,600)	(57,600)	(5,523,200)
Revenue from Biogas, 1m3, 100 AMD		-	-	740,098	740,098	740,098	5,180,688
Revenue from Fertilizer, 1kg, 100 AMD		-	-	999,133	999,133	999,133	6,993,929
TOTAL REVENUE	-	-	-	1,739,231	1,739,231	1,739,231	12,174,618
Cost savings				95,040	95,040	95,040	665,280
TOTAL BENEFITS				1,834,271	1,834,271	1,834,271	12,839,898
NET PROFIT OR LOSS	-	-	-	(3,343,329)	1,776,671	1,776,671	7,316,698
Interest rate	10%						
Interest rate	5%						
NPV at 10%	**-**	**-**	**-**	**(2,511,892)**	**1,213,490**	**753,482**	**3,301,681**
NPV at 5%	**-**	**-**	**-**	**(2,888,093)**	**1,461,672**	**1,145,258**	**4,901,852**

Conclusion

The cost-effectiveness analysis of the country-level breed type improvement and optimal feeding regime proves to be cost efficient. Further, the analysis made at farm level to reflect the cost-efficiency for a small and medium sized farm of investing in biogas production system, along with a fertilizer, also proves to be cost-efficient. The combination of those measures to be taken under the Mitigation scenario proposed in the scope of this Study, assume that the farm which will invest in importing Swiss breed type will profit starting from the first year. Since, the farm produces up to 308 kg manure per day, it will need to install at least 2 biogas reactors which will cost ~5,120,000 AMD. The farm can invest in biogas reactor starting from year 2025. As a result, the cumulative net cash flow will decrease, but still have a positive result. This means that starting from year 2025, the farm will continue to generate income and the total cumulative net cash inflow/profit for the whole period from 2021-2030 will be ~22,828,000 AMD (Table 31).

[106] Please see the full table with detailed calculations for each year from 2021 to 2030 in Annex 5: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 13 or manure production of 308 kg (calculated with fertilizers), 2021-2030.

Table 31: Summary cost benefit analysis: "Farm" & Biogas station

QUANTITATIVE ANALYSIS	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
BENEFITS											
Farm revenue	5,256,950	5,206,950	5,206,950	5,206,950	5,206,950	5,206,950	5,026,950	5,056,950	5,844,950	7,901,950	55,122,500
Biogas station revenue	-	-	-	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	12,839,898
TOTAL BENEFITS	**5,256,950**	**5,206,950**	**5,206,950**	**7,041,221**	**7,041,221**	**7,041,221**	**6,861,221**	**6,891,221**	**7,679,221**	**9,736,221**	**67,962,398**
COSTS											
Farm costs	4,996,286	3,460,286	3,460,286	3,460,286	3,460,286	3,460,286	4,029,686	5,196,460	4,627,060	3,460,286	39,611,206
Biogas station costs	-	-	-	5,177,600	57,600	57,600	57,600	57,600	57,600	57,600	5,523,200
TOTAL COSTS	**4,996,286**	**3,460,286**	**3,460,286**	**8,637,886**	**3,517,886**	**3,517,886**	**4,087,286**	**5,254,060**	**4,684,660**	**3,517,886**	**45,134,406**
NET BENEFIT OR COST	**260,664**	**1,746,664**	**1,746,664**	**(1,596,665)**	**3,523,335**	**3,523,335**	**2,773,935**	**1,637,161**	**2,994,561**	**6,218,335**	**22,827,991**
CUMULATIVE NET CASH FLOW	**260,664**	**2,007,329**	**3,753,993**	**2,157,328**	**5,680,664**	**9,203,999**	**11,97,934**	**13,615,095**	**16,609,656**	**22,827,991**	

4.2. Managed soils

4.2.1.1. "Business-as-usual" scenario

To calculate direct N_2O (3C4) and indirect N_2O (3C5) emissions from managed soils, the following N sources are included:

- Synthetic N fertilizers (FSN) (the data on the amount of imported synthetic N fertilizers);
- Urine and dung N deposited on pasture, range and paddock by grazing animals;
- N in crop residues (above and below ground), including from N-fixing crops and from forages during pasture renewal;
- The estimated N in crop residues (above and below ground);
- Organic N applied as fertilizer (e. g. animal manure).

To establish the "Business-as-usual" scenario, the crop production and FSN use patterns for 2017-2019 have been evaluated and compared to the standard for N fertilizer use.

Table 32 summarizes the comparison of the agricultural crop production for major crop groups in 2017 and 2030 under the "Business-as-usual" scenario. As described earlier in this Report, the crop production volumes have been taken from *"The Strategy"*.

Table 32: Gross yield of basic agricultural crops and perennial plantations in Armenia by 2030 under the "Business-as-usual" scenario.

Crop	Production, 2017, 1000 ton	Production, 2030, 1000 ton	Change from 2017 (%)
Cereals and legumes	302	804	166
Potato	543	652	20
Vegetable crops	784	910	16
Melons	216	246	14
Technical crop	NS	NS	NS
Feed crops	NS	NS	NS
Fruit and berries	361	610	69
Grape	210	273	30

The calculated agricultural land area for each of the main crop groups by 2030 is demonstrated in Table 33.

Table 33: Sawn area for main crop groups by 2030 under the "Business-as-usual" scenario

Crop	Sawn area, 2030, 1000 ha
Cereals and legumes	191.4
Potato	24.1
Vegetable crops	28.3
Melons	7.0
Technical crops	3.0
Feed crops	36.7
Fruit and berries	610
Grape	273

The following norms of N fertilizer use for basic crop groups are advised for optimal crop growth in professional literature[107,108,109,110] (Table 34).

Table 34: Standard norms of N fertilizer use for basic crop groups.

Crop	N, kg/ha
Cereals and legumes	90-120
Legumes	40
Potato	120-150
Vegetable crops	120-150
Melons	100
Technical	100
Feed	30-45
Fruit and berries	150
Grape	90-120

The calculation of FSN use in Armenia during the period 2017-2019 and their comparison with the theoretical calculations with the FSN use according to the agricultural standards (Table 35) demonstrates that the FSN use in Armenia was in 5-10% range with the theoretical calculations.

Table 35: Synthetic N fertilizer use in Armenia (Ni) and corresponding theoretical N fertilizer use according to the agricultural norms (Nr) in Armenia in 2017-2019.

	2017	2018	2019
NI, kg	32,831	32,183	26,390
NR, kg	34,945	30,617	28,750
Difference, %	6.4	-4.9	8.9

As such ***“Business-as-usual” scenario considered FSN calculations in 2030 according to the current agricultural fertilizer use standards. Total synthetic fertilizer uses in Armenia by 2030 is estimated to be 36,495 tons as N (equal to 78,204 tons of total volume).***

The direct N_2O emissions from managed soils (3C4) and indirect N_2O emissions from managed soils (3C5) under the “Business-as-usual” scenario is estimated by applying Tier 1 with default EFs based on the “National Greenhouse Gas Inventory Report of Armenia 1990-2017”.

CO_2 emissions from urea application (3C3) were estimated by the Tier 1 method using data on the projected amount of urea to be applied to soils in 2030, according to the “National Greenhouse Gas Inventory Report of Armenia 1990-2017”. ***The volume of urea to be applied to soils by 2030 compose 15,641 tons.***

107 Melikyan A. 2005. Horticulture.
Link: https://library.anau.am/images/stories/grqer/Gyughatntesutyun/banjarabucutjun.pdf

108 Matevosyan A. and Gyulkhasyan M. 2000. Crop Production.
Link: https://library.anau.am/images/stories/grqer/Gyughatntesutyun/gjul-busab.pdf

109 Morikyan E, Hovhannisyan G., and Arakelyan A. 1998. Fruit bearing orchard cultivation technology.
Link: https://library.anau.am/images/stories/grqer/Gyughatntesutyun/ptghatu.pdf

110 Margaryan A. and Shahinyan H. 1976. Fruit production.
Link: https://library.anau.am/images/stories/grqer/Gyughatntesutyun/ptghabutzutyun.pdf

Calculations of GHG emissions from biomass burning in croplands (3C1b) were made by applying Tier 1 method, according to "National Greenhouse Gas Inventory Report of Armenia 1990-2017"***. Biomass burning in cropland is considered to take place in 22,202 ha area by 2030 in Armenia under the "Business-as-usual" scenario.***

The estimated N in crop residues (above and below ground), based on the crop production volumes projected by the strategy was considered at 3,185,711 kg. GHG emissions in crop residues calculations were made by applying Tier 1 method, according to the "National Greenhouse Gas Inventory Report of Armenia 1990-2017".

Under the "Business-as-usual" scenario, by 2030 GHG emissions from the aggregate sources and non-CO_2 emissions sources on land category in Armenia are forecasted to reach 1,608 Gg CO_2 *eq.*, demonstrating 78.8% increase compared to GHG emissions from 2017. The largest contributor in GHG emissions in this sector is direct N_2O Emissions from managed soils, responsible for 78.8% of total GHG production from aggregate sources and non-CO_2 emissions sources on land.

Table 36: Emissions from aggregate Sources and Non-CO_2 Emissions Sources on Land under the "Business-as-usual" scenario by 2030

	CO_2 emissions, Gg	**CH_4 emissions, Gg**	**N_2O emissions, Gg**	**GHG emissions, as CO_2 eq.**
3.C Aggregate sources and non-CO_2 emissions sources on land				1,608
3.C.1.b. Emissions from biomass burning in cropland	0.00	0.22	0.01	6.27
3.C.3 Urea application	11.47	0.00	0.00	11.47
3.C.4 Direct N_2O Emissions from managed soils	0.00	0.00	3.96	1,226.6
3.C.5 Indirect N_2O Emissions from managed soils	0.00	0.00	1.01	312.26
3.C.6 Indirect N_2O Emissions from manure management	0.00	0.00	0.16	51.04

4.2.1.2. Mitigation scenario

GHG emissions from managed soils can be significantly reduced if certain operational measures are taken. There are two main groups of action to reduce GHG production from agricultural land and to mitigate global climate change. These include improving soil health to increase carbon sequestration and to reduction of GHG emissions from soils.

Increased carbon sequestration

Soil carbon sequestration is a process in which CO_2 is removed from the atmosphere and stored in the soil carbon pool. This process is primarily mediated by plants through photosynthesis, with carbon stored in the form of organic matter, or is stored in inorganic forms such as secondary carbonates.

It has been estimated that soil carbon sequestration could be scaled up to sequester 2–5 Gt CO_2 per year by 2050, with a cumulative potential of 104–130 Gt CO_2 by the end of the century[111]. Soil carbon sequestration, also known as "carbon farming" or "regenerative agriculture," can be accomplished in various ways, including:

[111] The Institute for Carbon Removal Law and Policy, an initiative of the School of International Service at American University. CARBON REMOVAL FACT SHEET. Link: https://www.american.edu/sis/centers/carbon-removal/upload/icrlp_fact_sheet_soil_carbon_biochar_181006.pdf

- reducing soil disturbance by switching to low-till or no-till practices or planting perennial crops;
- changing planting schedules or rotations, such as by planting cover crops or double crops instead of leaving fields fallow;
- managed grazing of livestock;
- applying compost or crop residues to fields for improved soil structure and function;
- erosion control (including irrigation).

The main climate change mitigation benefits of soil carbon sequestration are the increased soil productivity, improved climate resilience and reduced fertilizer use.

Yet, monitoring and verifying carbon removal via soil carbon sequestration is currently difficult and costly, and generation of quantitative data is subject to long focused investigations.

Reduction of GHG emissions from soils

Technically, high rates of soil GHG emission reduction is possible if N is applied to the soil only in the quantities required under the certain conditions. This approach is called a "4R Nutrient Stewardship". The framework of 4R Nutrient Stewardship considers reduced use of for crop production, and, subsequently, decreased climate change and environmental impacts of N fertilizer use. The four main principles of fertilizer use in accordance with 4R Nutrient Stewardship framework are:

- Use the **Right Source** of fertilizers that are best used by the target crop.
- Apply the **Right Rate** of fertilizer to match nutrient supply with crop requirements.
- Apply fertilizer at the **Right Time** to ensure nutrient availability when crop demand is high.
- Apply or maintain fertilizer in the **Right Place** where the crop can access the nutrients most effectively. [112]

Figure 16: 4R Nutrient Stewardship

Source: UNFCCC, 4R Nutrient Management for Emission Reductions and Increased Productivity
Link: https://unfccc.int/files/documentation/submissions_from_non-party_stakeholders/application/pdf/598.pdf

[112] UNFCCC, 4R Nutrient Management for Emission Reductions and Increased Options for Ammonia Mitigation, Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, 2014.

4R Nutrient Stewardship implementation is based on BMPs, that aim at the optimized fertilizer use. Selection of BMPs is site- and crop-specific. This means that a variety of factors, such as farm location and climatic conditions, grown crop types, soil biophysical and chemical composition, farm management practices are considered when selecting BMPs.

4R nutrient stewardship requires major quantitative data, such as soil biophysical and biochemical characteristics, including N content, crop type and N requirement, environmental and climatic conditions in the field, etc., to accurately estimate N inputs and crop outputs for each crop grown on the farm in a given year. 4R nutrient stewardship is in the basis of precision agricultural practices, including advanced technological applications that use hardware and sensors; data analysis and decision support systems, and commodity and whole-farm focus- the process whereby decision support systems and models are made commercially and utilized across whole farms, and not just individual fields.

Currently, quantitative data that will allow to estimate N inputs and crop outputs are missing for Armenian agricultural sector. No databases that provide information on current soil characteristics and environmental conditions exist in the country. The situation is more complex if considering projection of agricultural crop production and environmental conditions by 2030. Therefore, the generation of quantitative indicators for mitigation efficiency of soil carbon sequestration and reduced synthetic fertilizer use related to the GHG production from lands by 2030 in Armenia is not feasible.

4.3. Mitigation potential of GHG production from agriculture sector

The comparison of cumulative GHG production from Agriculture under the "Business-as-usual" and "Mitigation" scenarios for 2030 with the same in 2017 demonstrates that if no actions are taken to mitigate the GHG production from agriculture in Armenia, the estimated GHG production by 2030 will reach the level of 3,820 Gg CO_2 *eq.*, 58.7% of which will be attributed to the Livestock sector, and the remaining - to the GHG productions from Land. This is an estimated 98.1% increase of GHG production from 2017.

Table 37: GHG e emissions from agriculture sector under the "Business-as-usual" and "Mitigation" scenarios by 2030

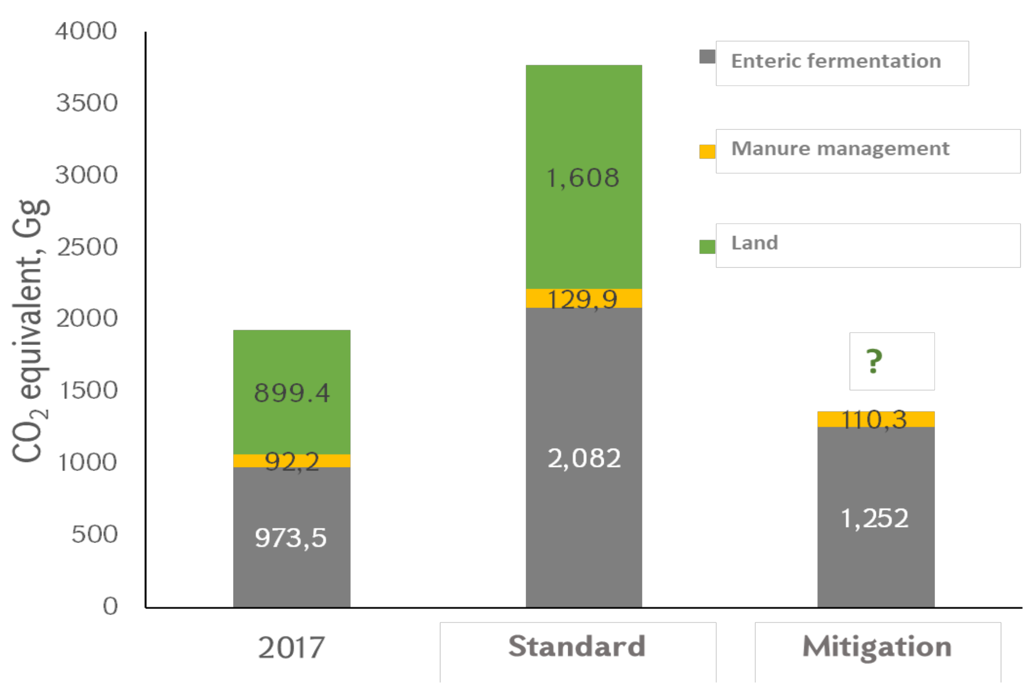
	2017	Business-as-usual, 2030	Mitigation, 2030
3A-Livestock			
3.A.1 - Enteric Fermentation	**973.5**	**2082**	**1254**
3.A.1.a - Cattle	849.0	1933	1105
3.A.1.a.i - Dairy Cows	*476.8*	*1137*	*691.4*
3.A.1.a.ii - Other Cattle	*372.2*	*796.6*	*413.6*
3.A.1.b - Buffalo	1.08	1.94	1.94
3.A.1.c - Sheep	106.9	126.2	126.2
3.A.1.d - Goats	3.64	5.77	5.77
3.A.1.f - Horses	3.91	3.63	3.63
3.A.1.g - Mules and Asses	0.41	0.19	0.19
3.A.1.h - Swine	8.30	10.48	10.48
3.A.1.j - Other (Rabbits, Fur bearing animals)	0.25	0.78	0.78
3.A.2 - Manure Management	**92.20**	**129.9**	**110.3**
3.A.1.a - Cattle	16.67	36.26	16.71
3.A.1.a.i - Dairy Cows	*8.79*	*19.40*	*10.32*
3.A.1.a.ii - Other Cattle	*7.88*	*16.86*	*6.39*

	2017	Business-as-usual, 2030	Mitigation, 2030
3.A.2.b - Buffalo	0.03	0.04	0.04
3.A.2.c - Sheep	49.43	58.38	58.38
3.A.2.d - Goats	0.97	1.53	1.53
3.A.2.f - Horses	0.25	0.23	0.23
3.A.2.g - Mules and Asses	0.03	0.01	0.01
3.A.2.h - Swine	19.55	24.69	24.69
3.A.2.i - Poultry	5.04	7.92	7.92
3.A.2.j - Other (Rabbits, Fur bearing animals)	0.25	0.78	0.78
3.B-Land			
3.C - Aggregate sources and non-CO_2 emissions sources on land	**899.82**	**1.608**	N/A
3.C.1.b - Biomass burning in croplands	6.80	6.27	N/A
3.C.3 - Urea application	2.72	11.47	N/A
3.C.4 - Direct N_2O Emissions from managed soils	671.3	1227	N/A
3.C.5 - Indirect N_2O Emissions from managed soils	181.8	312.3	N/A
3.C.6 Indirect N_2O Emissions from manure management	37.2	51.04	N/A

GHG emissions from enteric fermentation and manure management, e.g., under the "Business-as-usual" scenario, the estimated GHG production by 2030 will make 2,212 Gg CO_2 *eq.* This represents an estimated 108% increase from 2017. This is mainly attributed to the projected increased production of livestock in the country by 2030 to supply meat and milk to the population in accordance with the designated Strategy.

Under the "Mitigation" scenario, that considers changes in the agricultural production methods and incorporation of practices aimed at the reduction of the GHG production in Livestock and Land sub-categories. GHG emissions were possible to calculate only for the Livestock. Under the scenario, that considers changes in the breeds of the biggest emitter *cattle*, optimal feeding regime for chosen breeds, and AD for manure management are suggested. As a result, the estimated GHG production by 2030 is forecasted to fall to 1,364 Gg CO_2 *eq.* This is an estimated 28.0% increase from 2017, but a significant 38.4% decrease compared to the "Business-as-usual" scenario by 2030.

Figure 17: Total GHG production from agriculture sector in Armenia



A realistic change in reared Cattle breeds with increased meat and milk production capacities and their optimal feeding regimes, and therefore lower Cattle population size in Armenia by 2030 is forecasted to result in relatively lower animal population size. In turn, this will significantly reduce GHG emission from livestock enteric fermentation. Adding successful manure management practices, such as AD, will further reduce GHG emission from livestock.

171% of milk production increase is projected by 2030 compared to 2017, along with 213%, 167% and 182% of increase in beef, lamb and pork, production, respectively. The mentioned mitigation actions allow for only 28 % GHG production increase from Livestock compared to 2017. If no mitigation actions are taken, 108% of GHG production increase would be expected.

The mitigation potential of GHG production from lands, that considered soil carbon sequestration and reduced synthetic fertilizer use by 2030 was not possible to quantify.

5. Recommendations

5.1. Conditions for successful implementation of recommendations

The final objective of this Study is to develop recommendations on policies and measures for mainstreaming mitigation practices of climate change in Agriculture sector in Armenia. It is noteworthy, that the success of the mainstreaming is not only dependent on the specificities of the measures, processes and policies, but also on large scope of preconditions which enable their enforcement. The following preconditions are deemed important for implementation of any measure and need to be considered while addressing the mitigation challenges in Armenia:

- *Information availability*

  Effective mainstreaming is largely dependent on information availability, including climate data and potential implications of climate change. The Study indicates lack of data accuracy and completeness, which is an obstacle for making rigid quantitative analysis. The available data lags in time period, which also makes the information not timely. Therefore, it is encouraged to make continuous efforts in order to improve the data quality and coverage, its completeness, accuracy and timeliness. For this, an up-to date reporting and monitoring system should be introduced which should serve as a centralized platform for current data.

- *Awareness*

  Lack of awareness can become a serious obstacle for mainstreaming mitigation processes. The potential sources of climate change and their expected impact, as well as the GoA strategy to support mitigation activities should be widely spread over participating stakeholders. GoA staff, financial institutions, private sector and smallholder farms should be aware of the climate change-related strategic aspects and actions, opportunities and needs and adjust their activities correspondingly.

- *Coordination and monitoring*

  Climate change mitigation activities are initiated at various level and involve a wide range of stakeholders which need to be properly coordinated and the result monitored. Thus, it is encouraged to communicate and build capacity for different representatives in order to make the optimal level of efforts for the proper coordination of the activities and undergoing programmes. Targets should be specifically identified and the results monitored against those targets. Quantitative and qualitative analysis for the achievements should be made to understand the risks, correspondence and additional needs.

5.2. General recommendations

As a result of the conducted Study, general recommendations and sector-specific measures were developed to address the challenges which make agriculture sector more vulnerable to climate change and create additional barriers for its mitigation activities.

There are a number of issues for mitigation of climate change in agriculture sector, which require careful consideration and further improvement. By addressing those issues through the introduction/revision of approaches and policies, capacity building and awareness raising, approving data management procedures, it is expected that the effectiveness of the suggested measures and activities may substantially increase.

Certain mitigation-driven actions in agriculture could have positive adaptation consequences (e.g., carbon sequestration projects with positive drought preparedness aspects). Furthermore, certain adaptation-driven actions also may have positive impact for mitigation. Consequently, the planned programmes and measures to reduce emissions in the agricultural sector will need to be designed and implemented in synergy with adaptation in response to climate change.

Summarizing the assessment results, as well as taking into account international best practices, the GHG emissions in agriculture sector in Armenia can be reduced by:

- ✓ Reducing enteric CH_4 emissions from livestock management.
- ✓ Reducing CH_4 and N_2O emissions from the storage, processing and application of manure.
- ✓ Increase carbon capture in the soil by improving soil management techniques and preventing its release.
- ✓ Reducing N_2O emissions from soils.

The general recommendations which relate to the institutional and technical capacity issues and development are provided next in summary and then in more detail:

Summary

General recommendations
✓ Elaborate a national program on climate change mitigation in agriculture sector. ✓ Establish an institutional set-up across sectoral national bodies to coordinate the development and implementation of climate change mitigation in agriculture. ✓ Work with relevant funding organizations and donors such as Green Climate Fund, Global Environment Facility, the World Bank, Asian Development bank, KFW, EU, other development partners, donors, private sector, etc., in support of implementation of Climate Change mitigation actions in the field of agriculture. ✓ Creation of a centralized platform for data and knowledge interchange on climate change mitigation as well adaptation including depositary of case specific mitigation (adaptation) models and local and international good practices to be utilized to contribute to GHGE mitigation. ✓ Consolidate the strategic and policy efforts for promotion of the potential of organic farming as a climate change mitigation and adaptation strategy. ✓ Strengthen national institutional capacities of technical knowledge and expertise on climate change mitigation and adaptation. ✓ Strengthen national institutional capacities and technical facilities to generate, collect, analyze and use data information that enhances their ability to address climate change adaptation and mitigation. ✓ Organize awareness raising campaigns among farmers, local public institutions and other beneficiaries on climate change mitigation and adaptations.

- ✓ Strengthen capacities of farmers through commonly used approaches such communication, training, practical on-job training demonstration farms, farmers' field schools and establishing producers' networks for knowledge sharing. Share knowledge and information through ICTs.
- ✓ Strengthen capacities of agricultural advisory, extension and support services which includes facilitates practice change for mitigation and production enhancement, by providing access to good practices and technologies and building capacity to implement them.

Agriculture sector-specific mitigation measures:

1. Introduction of efficient & robust animals and improved feeding
2. Introduction of Conservation Agriculture
3. Reducing GHG emissions from nitrogen fertilizer management
4. Expand the sown area of leguminous crops on arable land
5. Introduction of anaerobic digestion

Issue: *Inadequate policy and governance mechanisms for efficient implementation of mitigation actions in the agriculture sector*

Recommendation:

- ✓ Elaborate a national program on climate change mitigation in agriculture sector;
- ✓ Establish an institutional set-up across sectoral national bodies to coordinate the development and implementation of climate change mitigation in agriculture.

Issue: *Lack of financial resources*

Recommendation:

- ✓ Work with relevant funding organizations and donors such as Green Climate Fund, Global Environment Facility, the World Bank, Asian Development Bank, KFW, EU, other development partners, donors, private sector, etc., in support of implementation of Climate Change mitigation actions in the field of agriculture.

Issue: *Availability of data (available data is often incompatible, inaccurate, unreliable and outdated)*

Recommendation:

- ✓ Creation of a centralized platform for data and knowledge interchange on climate change mitigation as well adaptation including depositary of case specific mitigation (adaptation) models and local and international good practices to be utilized to contribute to GHGE mitigation.

Issue: *Lack of knowledge on climate change mitigation and adaptation technologies among public intuitions, public and private advisory services, input supplies, farmers, etc.*

Recommendation:

- ✓ Strengthen national institutional capacities of technical knowledge and expertise on climate change mitigation and adaptation;

- ✓ Strengthen national institutional capacities and technical facilities to generate, collect, analyze and use data information that enhances their ability to address climate change adaptation and mitigation;
- ✓ Organize awareness raising campaigns among farmers, local public institutions and other beneficiaries on climate change mitigation and adaptations;
- ✓ Strengthen capacities of farmers through commonly used approaches such communication, training, practical on-job training demonstration farms, farmers' field schools and establishing producers' networks for knowledge sharing. Share knowledge and information through ICTs.

Issue: *Predominance of small-scale, subsistence and semi-subsistence farms which low purchasing power and small scale making good agricultural practices and technologies uptake unaffordable and unattractive*

Recommendation:

- ✓ Strengthen capacities of agricultural advisory, extension and support services which includes facilitates practice change for mitigation and production enhancement, by providing access to good practices and technologies and building capacity to implement them.

5.3. Agriculture sector specific mitigation measures

In this section, sector specific measures are developed, demonstrating the issue, why the measure is important, the objective for the implementation of the measure, the main activities characterizing the measure, agencies engaged in the decision-making processes and implementation of the measure, required finance, human and other resources, and expected outcome.

Measure: ***Introduction of Efficient & Robust Animals and Improved Feeding***	
Issue: *Current most common cattle breed in Armenia has significantly lower meat and milk production than highly productive breeds. Along with inefficient feeding, thisresults to relatively higher GHG production from enteric fermentation.*	***Objective:*** To achieve a replacement of currently common cattle breeds with purebred Swiss and mixed-breed cattle, along with improved feeding in Armenia by 2030.

Activities for measure implementation:

- ✓ Develop policies and incentivize in the area of introduction of new, higher productivity cattle breeds in the country.
- ✓ Introduce Government support program for enhancing the introduction of Swiss breed cattle to the country.
- ✓ Introduce Government support program for enhancing the introduction of artificial insemination for breeding Swiss breed cattle in the country.
- ✓ Develop and introduce efficient animal feed and forage management practices system.
- ✓ Establish close cooperation between agri-food industry, breeding organizations, feed producers and research institutes.
- ✓ Improve the knowledge of farmers regarding rearing and maintenance of new breeds and optimal feeding strategies (including advise and training, on-job training, demonstration, etc.).

✓ Pilot programmes in areas where most benefit is expected, such as changing animal breeds and providing improved feeding regime in selected leading animal farms or organization of high-quality feed production operations in the country, including efficient and modern methods of high value feed crop growth and harvesting and storage, that will subsequently result in increased production volume and reduced losses of feed nutrient value.

Agencies engaged in the implementation of the measure:	***Implementation cost and other resources needed:***
- RA Government - Donor organizations - Private investors - Farmers - Private agencies and NGOs engaged in agricultural development projects - Universities and research institutions - Veterinary services	Upfront investment costs, including costs of procurement and import of high-breed cows. Cost of implementation for breeding programme using artificial insemination. Efficient infrastructure, know-how and expertise. Agricultural lands and machinery for high quality feed production.

Background information:

The use of efficient and robust animals that are able to increase their productivity per unit of input is a cornerstone for reduced level of GHG production without compromising economic viability of the sector. Optimal feeding is crucial for achieving desired productivity levels. Over the years, international breeding organizations have been selecting high productivity animals for their breeding and reproduction programs. This measure has additional benefit of reduced GHG production from enteric fermentation.

Description of the measure:

✓ The implementation of the measure requires:

- state support in form of policies and regulations for the activities, as well as introduction of state support programs (incentives and subsidies) to farmers engaged in cattle breeding. The programs have to be based on differential approaches for different sized farms.
- state support programs for establishment of animal breeding capacities in the country. There should be incentives for breeders to include mitigation of GHG emissions as a target in their breeding programmes.
- state support for establishment of efficient feed production and management.

✓ Improved cooperation and interaction between breeding organization, stakeholders, and the marketplace (including any incentives from governments) is a must for success of this measure.

✓ Currently, there is a variability of know-how of animal breeds, optimal feeding regimes and overall livestock production in cattle farmers in Armenia, with higher availability of information and resources for the larger industrial farms. The measure, thus, should consider capacity development of small and medium sized farm owners through awareness raising, training programs, demonstration farms, on job training/workshops.

✓ Pilot programmes may serve as a best practice for a larger uptake of the measure. Support of donor organizations is highly important for the implementation.

Constraints:

- Lack of financial resources and lack of capacity to find financial resources;
- Small farms with no resources and/or motivations for the change.

Expected outcomes:

Introduction of Efficient & Robust Animals, large-scale use of artificial insemination and Improved Feeding is expected to result in:

- ✓ Estimated 43% decrease of GHG production from enteric fermentation compared to the "Business-as-usual" scenario by 2030.
- ✓ Increased farmer income due to high productivity.

Measure: *Introduction of Conservation Agriculture*	
Issue: *The level of conservation agriculture in Armenia is rather low. Currently, only 2,000-2,300 ha lands are cultivated under this practice, mainly in Shirak and Lori marzes.*	***Objective:*** to reach around 10-12 thousand ha of cultivated land in Armenia with this technology by 2030.
Activities for measure implementation: • Introduce the subsidy and/or support projects for farmers involved in conservation agriculture. • Establish agricultural machinery pools for introduction and promotion of conservation agriculture. • Introduce technology transfer and capacity building through establishment of demonstration sites and on-job training in cooperation with the research centers. • Raise capacities of the farmers through training and awareness raising campaigns. • Build the technical capacities of the public and private advisers, the relevant staff of scientific and research institutions to transmit and disseminate quality information on conservation agriculture to farmers.	
Agencies engaged in the implementation of the measure: - RA Government - Donor organizations - Private investors - Farmers - Private agencies and NGOs engaged in agricultural development projects	***Implementation cost:*** Upfront investment costs, including costs of procurement of specialized planting and other supporting equipment and machinery. Staffing costs. Costs of awareness raising campaigns and organization of training. **Other resources needed:** Experts in conservation agriculture
Background information: Conservation Agriculture (CA) or no-till aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. In this case, the main disturbance to the soil between crops is the planting operation with specially adapted ground engaging planter.	

In this case, weed control relies on use of multiple combinations of chemical sprays of herbicides in several applications. Applications of the minimum tillage ensure increase of soil organic matter and water retention, decrease pressure on soil and weaken soil compaction, increase crop tolerance to climate variations, stabilize and improve agriculture productivity, reduce use of fossil fuel and mineral fertilizer, eliminate combustion of organic by-products, mitigate GHG emissions and minimize run-off and soil erosion. It helps to assure the positive balance between carbon inputs and carbon outputs. In many cases, CA has been proven to reduce greenhouse gas emissions by farming systems and enhance their role as carbon sinks. Sequestration of soil organic carbon by farmers also contributes to the mitigation of greenhouse gases.

Description of the measure:

- ✓ The implementation of the measure requires state support in form of policies and regulations, as well as introduction of state support programs (subsidy mechanisms and other relevant tools) to farmers engaged in CA to facilitate the practical use of conservation methods.
- ✓ Nowadays the farmers are not well aware of the techniques used under CA. The measure, thus, considers, capacity development of farmers through awareness raising, training programs, demonstration farms, on job training/workshops, so that they will be better acknowledged about the CA itself, as well as those techniques and methods used in CA, its benefits, main products and technology used for CA, and corresponding practices become more familiar to them.
- ✓ The implementation of the measure also considers the need for CA agriculture machinery and equipment including no-till and minimum-tillage seeder. This can be facilitated through project(s) in establishment of agricultural machinery pools with necessary agricultural machinery and equipment for introduction and promotion of CA in mountainous and pre-mountainous regions of Armenia (Syunik, Gegharkunik, Shirak, Lori, Tavush, Kotayk, Aragatsotn and Vayots Dzor marzes). Public private partnership models could be used for establishment and running those pools.
- ✓ Pilot programmes may serve as a best practice for a larger uptake of CA. Increase of national capacities and pilot-testing, demonstrating the CA practices, with the overall objective of technology transfer and capacity building should be done. Support of donor organizations is highly important for the implementation of this measure.

***Constraints*:**

- Lack of attention by the state and implementing agencies in prioritization of this issue.
- Lack of financial resources.
- Lack of experienced and trained technical personnel including advisers.
- Lack of required agricultural machinery, equipment.
- Transition period, which is around five years, is one of the main constrains for farmers.
- Cultural factors such as farming traditions, conservatism.
- Lack of know-how about how to implement conservation agriculture (e.g., different methods for controlling weeds and managing residues).
- Small farms and excessive land fragmentation.
- Rotation of crops (legumes and cover crops).

Expected outcomes:

Introduction of CA is expected to result in:

- ✓ Significant labor savings and reduction of fuel costs.
- ✓ Reduction of the number of tractors and other agricultural machinery involved in fieldwork, along with reduction of their capacities, thus leading to fall in fuel consumption and thus CO_2 emissions.
- ✓ Reduction of time for field activities, which allows organizing field activities in optimal time.
- ✓ Introduction of long crop rotation including cover crops.
- ✓ Accumulation of soil moisture in areas with low precipitation and dry conditions.
- ✓ The agro-productive properties and biological activity of the soil are improved and the amount of organic matter in the soil increases.
- ✓ Soil erosion decreases, the water erosion decreases 1.5-3 times, while deflation decreases by 6-10 times, soil overcrowding decreases.
- ✓ Cover crops and long crop rotation enable better control of weeds, thus reducing the use of pesticides compared with the no-tillage approach alone.
- ✓ Conservation allows organic carbon to accumulate in the soil, which, in the case of traditional cultivation is mineralized and enters the atmosphere. The advanced technology allows avoiding these losses, which make up 50% of the soil organic matter.
- ✓ CA provides a strategic entry point for sustainable soil management. Furthermore, diverse, and improved productivity, through such newly introduced/adjusted farming practices, has a potential for Armenian farmers to minimize the risks associated with current climate, projected climate and food security.

Crop rotation and crop diversification improve the resilience of crops against climate change, increase productivity, decrease pests and diseases, improve nutrient efficient cycling, improving soil quality and in the long-term contributing to low GHG emissions.

Measure: ***Reducing GHG Emissions from Nitrogen Fertilizer Management***

Issue: *The application of fertilizers, in particular nitrogen fertilizers, in Armenia is carried out without controlling and maintaining the rules of agro-chemistry, with violation of the norms and methods of their application.*	***Objective:*** to improve nitrogen fertilizer application, optimize their use and GHG emissions from nitrogen fertilizer by 2030.

Activities for measure implementation:

- ✓ Develop and introduce good agricultural practice (GAP) on plant nutrient management and fertilizer use.
- ✓ Develop guide(s) on good agricultural practices on implementation of scientifically grounded crop rotation systems for different climatic zones, soil, crop types, etc.
- ✓ Introduce mechanisms for promotion of wide use of crop rotation systems.
- ✓ Introduce mechanisms for decreasing the import and use of urea-based fertilizers.

- ✓ Strengthen capacities of farmers, agricultural advisory, extension and support services, technically competent institutions, authorities, including staff of agrochemical services on plant nutrient management and fertilizer use.
- ✓ Organize awareness raising campaigns among farmers, local public institutions and other beneficiaries on sustainable soil and water management, crop rotation and GAP on fertilizer management.
- ✓ Application of fertilizers should be based upon soil analysis and/or recommendations of technically competent institutions, authorities or personnel.
- ✓ Expand the existing state support programme / introduction of modern irrigation systems.
- ✓ Promote introduction of crop rotation including legumes crops in the rotation.

Agencies engaged in the implementation of the measure: - RA Government - Donor organizations - Private investors - Farmers - Agrarian University, Scientific Institutions - Implementing agencies, NGOs and private companies engaged in agricultural development projects	***Implementation cost:*** Upfront investment costs, including procurement of specialized fertilizer application machinery. Staffing costs. Costs of awareness raising campaigns and organization of training, cost of R&D.

Background information: Using fertilizers are among the most important yield-generating factors and are critical for crop production, and, at the same time, for maintenance of soil fertility. It is a highly cost-consuming procedure with significant impact on the environment. Fertilizer application normally results in increased yield with diminishing returns until maximum yield is reached. However, part of nitrogen fertilizers leaches into water or escape in gaseous form into atmosphere.

There are certain farmers in Armenia, especially fruit, vegetable and potato producers that often apply extra nitrogen to ensure highest yield. Applying too much nitrogen fertilizer reduces profitability and increases water pollution, air pollution, and leads to increased losses of nitrogen. This can happen through leaching, or as gaseous nitrogen compounds such as N_2O and contribute to the GHG emissions. Inappropriate / excessive application of fertilizer can reduce yield, which is not only environmental problem but also economic issue for the farmers.

Ammonia emissions from fertilizer applications are dependent on fertilizer type, weather and soil conditions. Emissions from urea-based fertilizers are larger than from other fertilizer types because rapid hydrolysis of urea cause a localized rise in pH. In particular, NH_3 emissions from urea-based fertilizers (typically 5%–40% N loss as NH_3) are much larger than those based on ammonium nitrate (typically 0.5%–5% N loss as NH3)[113].

Although ammonium nitrate is the main form of nitrogen fertilizer used in Armenia, there is a tendency for increasing the import and use of urea-based fertilizers. The import of carbamide accounted for 4.1% of total

[113] Options for Ammonia Mitigation, Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, 2014. Link: http://nora.nerc.ac.uk/id/eprint/510206/1/N510206CR.pdf

imported nitrogen fertilizers in 2017, 7.0 % in 2018 and 10.8 % in 2019. The reason could be higher cost of ammonium nitrate.

The use of methods to reduce NH_3 emissions from urea-based compounds makes an important contribution to overall NH_3 emission reductions in agriculture. If applied at agronomically sensible rates and times, improved crop N uptake will be the main benefit of mitigating NH_3 emissions, with minimal increases via the other loss pathways (e.g., nitrate leaching, denitrification). In addition, by reducing NH_3 emissions, a similar reduction in indirect N losses is expected (e.g., by reduced leaching and denitrification from forest soils)[114].

Applying nitrogen fertilizer using the right source, right rate, right time, and right place increases crop yield and profitability. These management practices can also reduce GHG emissions while improving profitability.

Description of the measure:

- ✓ The implementation of the measure requires state support in form of policies and regulations for the activities, as well as introduction of state support programs (through subsidy mechanisms and other relevant tools), donor organization support in developing GAP, organizing capacity development and awareness raising programmes.
- ✓ It is recommended to elaborate a good agricultural practice (GAP) on the bases of the 4R Nutrient Stewardship, which applies nitrogen fertilizer from the Right source at the Right rate, Right time, and Right place. The GAP objective is to provide a framework document which will guide farmers to achieve cropping system goals, such as increased production, increased farmer profitability, enhanced environmental protection and improved sustainability.
- ✓ Nowadays the farmers mainly are not aware of the techniques of management and using plant nutrients and fertilizers. The measure, thus, considers, capacity development of farmers, farm advisers, input suppliers through awareness raising, training programs, demonstration farms, on job training/workshops. The objective is to apply fertilizers using the right source, rate, time, and place (the 4 Rs) to increase crop yield and profitability and reduce N_2O emission, thus reducing an important source of GHG from agriculture while saving funds. The 4 Rs should be used all together in a comprehensive plan appropriate for the cropping system, and accounting for all sources of nitrogen input to crop fields.
- ✓ Government, donor organizations, private investors support is needed to promote uptake of fertilizer application machinery.
- ✓ Precision farming (i.e., using on-farm modern technology, using satellite data and tools for precise navigation) enhances the efficient use of inputs, such as fertilizers and pesticides, and can reduce water use and maintain soil structure. This measure requires investments in new machinery, technologies and the knowledge to use those technologies.

Constraints:

- Lack of knowledge and capacities;
- Farm structure including small size of farms and excessive land fragmentation;
- Lack of attention by implementing agencies in the prioritization of this issue;

[114] Nitrogen Fertilizer Management &Greenhouse Gas Mitigation Opportunities.
Link: http://climatesmartfarming.org/wp-content/uploads/2019/02/Nitrogen-Fertilizer-Management.pdf

- Lack of financial resources and lack of capacity to find financial resources;
- Lack of institutional capacities;
- Lack of fertilizer application machinery.

Expected outcomes:

This measure is expected to:

- ✓ Improve fertilizer management.
- ✓ Reduce the cases of applying excessive nitrogen fertilizer, thus minimize nitrogen leaching, and N_2O emission.
- ✓ Reduce losses due to volatilization, particularly of ammonia.
- ✓ Increase yields and profitability, reduce N fertilizer requirements, maintain soil fertility, reduce soil erosion, and decrease weeds, pest and diseases.

Measure: *Expand the Sown Area of Leguminous Crops on Arable Land*

Issue: *The area of leguminous crops such as peas, beans, lentils, chickpeas are only less than 1% of total sown areas and 0.5% of the arable land of the country (2015-2020).*	***Objective:*** to have at least 5% of leguminous crops in sown areas in 2030.

Activities for measure implementation:

- ✓ Introduce and expand the existing state support programmes on promotion of leguminous crops production.
- ✓ Increase awareness and capacity of farmers.

Agencies engaged in the implementation of the measure: - RA Government - Donor organizations - Private investors - Farmers - Agrarian University, scientific institutions - Implementing agencies, NGOs and private companies engaged in agricultural development projects.	***Implementation cost:*** Upfront investment costs, including procurement of agricultural inputs and agricultural machinery and equipment (including precision seeders), specialized cleaning and packaging equipment.

Background information: Leguminous crops improve environmental balances because the biological fixation of atmospheric nitrogen reduces the need to use nitrogen fertilizer. Biological nitrogen fixation by leguminous crops through symbiosis with bacteria in nodules of the root system, provides input of nitrogen in many agricultural soils. The scientific literature indicates that the ability of the leguminous to fix their own nitrogen via a symbiosis with rhizobia bacteria reduces emissions of fossil energy-derived CO_2 and results in lower N_2O fluxes compared to cropping and pasture systems that are fertilized with industrial nitrogen. Sowing leguminous species on arable land would improve the fertility of the farm's agro-system. According to the

SCRA, the area of leguminous crops such as peas, beans, lentils, chickpeas are only less than 1% of total sown areas and 0.5% of the arable land of the country (2015-2020), while the degree of self-sufficiency of leguminous is only 38.2% in 2019.

The area of perennial grass (such as sainfoin and alfalfa, which also belong to the Fabaceae/Leguminosae family) sown in past years is around 45 thousand ha in 2020 which is 20% of total sawn area and 10% of total arable land.

Description of the measure:

- ✓ Introduce and expand the existing state support programmes on promoting production of legumes crops including seed breeding and production.
- ✓ Increase awareness and capacity of farmers on benefits of legumes crops through communication, training, demonstration farms, farmers' field schools and using information and communication tools.
- ✓ Introduction of precision agriculture techniques (such as machine guidance and variable rate nitrogen application, on-farm modern technology, using satellite data and tools for precise navigation) enhances the efficient use of inputs, such as fertilizers and pesticides, and can reduce water use and maintain soil structure. This measure requires investments in new machinery and the knowledge to use the new technologies.

Constraints:

- Lack of knowledge and capacities.
- Difficulties to convince farmers to move towards growing leguminous crops.
- Farm structure including small size of farms and excessive land fragmentation.
- Lack of attention by implementing agencies in the prioritization of this issue.
- Lack of financial resources and lack of capacity to find financial resources.
- Lack of agricultural machinery and equipment for leguminous crops.

Expected outcomes:

This measure is expected to result in:

- Decrease of direct N_2O emissions from soils (substitution of mineral nitrogen fertilizers). At least 40kg N/ha[115] reduction in mineral fertilization for the next crop would be available due to the biological N fixation.
- Reduction of using 464 tons of nitrogen fertilizers (290 thousand ha*4%*40 kg/ha=464 tons).
- More independence regarding feedstuffs could be another benefit.
- Positive impact on soil structure improving via involving leguminous crops in the rotation.
- Protein-rich feedstuffs for livestock could be another benefit.
- Additional income for farmers compared with cereals production.
- Increase yield of following crop.

[115] https://library.anau.am/images/stories/grqer/Gyughatntesutyun/gjul-busab.pdf

Measure: ***Introduction of agroforestry (windbreaks)***

Issue: *Following the land privatization in the country, due to the energy crisis of the 90s, massive deforestation was carried out including the windbreaks (shelterbelts).*

Objective: Establish around 10 thousand ha of agroforestry (windbreaks) in Armenia by 2030.

Activities for measure implementation:

- Introduce programs, including state support programs for establishment and maintenance of agroforestry (windbreaks).
- Build the technical capacities of the public and private extension services and advisers to transmit and disseminate information on benefits and services of agroforestry to the farmers, other land users and partners and support them to establish and maintain agroforestry.
- Organize awareness raising campaigns among farmers, local public institutions, NGOs, other beneficiaries and partners on benefits of the agroforestry systems.
- Foster public-private partnerships that will facilitate implementation of this measure.

Agencies engaged in the implementation of the measure:

- RA Government
- Donor organizations
- Private investors
- Farmers
- Private agencies and NGOs engaged in agricultural development projects

Implementation cost:

High investment costs for establishment and maintenance of agroforestry (windbreaks). Costs of awareness raising campaigns and capacity building training.

Other resources needed:

Natural resource professionals.

Background information: Agroforestry is integration of trees or shrubs with crop to create environmental, economic and social benefits for land users and smallholder farmers at all levels. It can increase land productivity and efficiency in the use of water and other resources and protect against soil erosion as well as serve carbon sequestration objectives. It will also bring mitigation and adaptation synergy in agriculture sector, since it is soil carbon sequester and can increase resilience to extreme weather events (e.g., drought and floods), improve agriculture productivity, increase food production and provide livelihood specially during dry years.

Description of the measure:

- ✓ The implementation of the measure requires state support in form of policies and regulations, as well as introduction of support programs, including state support programs for establishment and maintenance of agroforestry (subsidy mechanisms, financial incentives and other relevant tools) involving local public administrations, land users including farmers, NGOs and other beneficiaries and partners.
- ✓ Awareness raising and capacity development of farmers through training programs, workshops, demonstration, etc., so that they will be better acknowledged about the benefits and services that agroforestry provides.

- ✓ Implement pilot programmes, which may serve as a best practice for a larger uptake of the suggested measure.
- ✓ Increase national capacities and availability of information and tools that will help natural resource professionals, advisers to provide technical and educational assistance.

***Constraints*:**

- Lack of attention by the state and implementing agencies in prioritization of this issue.
- Small farms and excessive land fragmentation.
- Lack of financial resources.
- Lack of experienced and trained natural resource professionals, technical personnel including advisers.
- Cultural factors such as farming traditions, conservatism.

Expected outcomes:

Introduction of this measure is expected to result in:

- ✓ Protection of valuable topsoil and decrease of soil erosion.
- ✓ Improved agro-productive properties and biological activity of the soil and increased amount of organic matter in the soil.
- ✓ Accumulation of organic carbon in the soil.
- ✓ Improved soil quality and long-term contribution to low GHG emissions.
- ✓ Accumulation of soil moisture in areas with low precipitation and dry conditions.
- ✓ Increased productivity of crops.
- ✓ Increased resilience to extreme weather events.
- ✓ Enhanced biodiversity and landscape diversity.

Measure: ***Introduction of anaerobic digestion***	
Issue: *Anaerobic digestion of animal manure for biogas production is underdeveloped in Armenia.*	***Objective:*** To achieve AD levels of 79% of manure from Large cattle farms and 47% of manure from Small cattle farms in Armenia by 2030.

Activities for measure implementation:

- ✓ Develop policies in the area of AD installation and use in the country;
- ✓ Develop regulations in the area of environmental impact of agricultural farms;
- ✓ Create professional workforce and expertise for AD;
- ✓ Improve the knowledge of farmers regarding AD (including advise and training), specifically for smallholders;
- ✓ Invest in technological apparatus and adequate infrastructure for manure collection, storage and AD;
- ✓ Organize awareness raising campaign for the introduction of AD for manure management;
- ✓ Demonstrate and pilot AD systems.

Agencies engaged in the implementation of the measure:	***Implementation cost and resource use:***
- RA Government - Donor organizations - Private investors - Farmers - Private agencies and NGOs engaged in agricultural development projects - Universities and research institutions	Upfront investment costs in technological apparatus and infrastructure. Farms with manure collection infrastructure. Anaerobic digestion and biogas collection systems. Engineering experts.

Background information: Anaerobic digestion of manure with subsequent biogas production, capture and use allows reduced environmental impact of manure management, including decreased GHG production, nutrient leaching to the environment, microbiological contamination, etc. AD has also economic benefits, such as production and use of biogas as an alternative energy source, use of digestate as fertilizer, reduced financial burdens of manure storage and/or transportation.

AD technology is highly suitable in both developed and developing countries, under different operational and climatic conditions, with tailor made solutions for each specific setting.

Description of the measure:

- ✓ The implementation of the measure requires state support in form of policies and regulations for the activities, as well as introduction of state support programs (incentives and subsidies) to farmers engaged in AD. Broader environmental regulations (for odor and water quality) should be also in place.
- ✓ The implementation of the measure requires models of smart cattle farms with efficient manure collection units. The establishment and operation of smart animal farms are in the focus of Government Decree N269-L of RA (2019), "On Approval of the State Assistance Program for the Construction or Reconstruction of Small and Medium-Sized "Smart" Livestock Barns and Their Technological Provision", however, are still in introduction stage.
- ✓ Currently AD is not a widespread technology in Armenia, suggesting lack of awareness, technological knowledge and expertise in this field. Transferring the basic principles, education, information, are fundamental to the success of manure management in the country. Customized training programmes and demonstration facilities are needed along with an enabling financial and technical infrastructure.
- ✓ AD and biogas collection requires investment in technological equipment, specifically for the large industrial-scale biogas digesters.
- ✓ Demonstration and pilot programmes may serve as a best practice for a larger uptake of AD, with the overall objective of technology transfer and capacity building.
- ✓ Support of donor organizations and financial investments are highly important for the implementation of this measure. In medium and small sized farms, simple digesters may require support for capital investments. Yet, they have relatively short pay-back periods.

Constraints:

- Lack of time attributed to the implementation of the measure;
- Lack of attention by implementing agencies in the prioritization of this issue;
- Lack of financial resources and lack of capacity to find financial resources;
- Lack of suppliers of required AD systems;
- Lack of know-how;
- Social and cultural barriers.

Expected outcomes:

Introduction of AD is expected to result in:

- ✓ Estimated 15% decrease of GHG production from Livestock compared to the "Business-as-usual" scenario by 2030.
- ✓ Starting from year 4 from AD installation, the farms will generate income from biogas and fertilizer production.
- ✓ Broader environmental protection, such as reduced pollution of aquatic and terrestrial environments will be achieved.
- ✓ Reduced reliance on fossil fuel consumption with subsequent increased energy independence, reduced environmental impact and increased economic benefits.

5.4. Risk assessment and mitigation

Overview of risk and mitigation matrix is given next, providing the possible political, economic, institutional financial and social risks, the level of impact (high, medium, low)) and probability of occurrence (high, medium, low), as well as possible mitigation measures.

	Risk	Impact	Probability	Management/Mitigation Measures
POLITICAL RISKS				
P1	Diversion the Government´s focus and resources away from climate change mitigation and adaptation in the sector due to the political changes in the country	*High*	*Medium*	Establish an institutional set-up across sectoral national bodies to coordinate the activities. Awareness raising of decision-makers and general public.
ECONOMIC RISKS				
E1	Low rate of economic growth and changes in the economic situation could divert the Government's focus and resources away from climate change mitigation and adaptation in agriculture	*High*	*Medium*	Adopt measures and actions to find new financial sources including private sector. Work with relevant funding organizations and donors, other development partners, in support of implementing the proposed mitigation actions.
E2	The proposed actions may not be fully implemented by the Government due to budgetary constraints and/or change in the priorities.	*High*	*Medium*	Adopt measures and actions to find new financial sources including private sector. Work with relevant funding organizations and donors, other development partners, etc. in support of implementation of the proposed mitigation actions.
INSTITUTIONAL RISKS				
I1	Lack of sufficient capacities for implementation actions at policy level leading to delays in implementation and underachievement of results	*Medium*	*High*	Establish strong management mechanisms for implementation of the proposed actions. Capacity development of relevant institutional stakeholders.

	Risk	Impact	Probability	Management/Mitigation Measures
I2	Lack of interest in capacity building by institutional beneficiaries	*Medium*	*Medium*	Enhance awareness and provide necessary incentives to trigger interest of institutional stakeholders for relevant capacity building activities
FINANCIAL RISKS				
F1	Lack of financial resources for mitigation of climate change in agriculture	*High*	*High*	Work with relevant funding organizations and donors, other development partners, etc. to raise additional funds
SOCIAL RISKS				
S1	Resistance with regard to abandoning traditional agriculture and low level of interest to use the suggested new technologies	*Medium*	*Medium*	Organize awareness raising campaign on benefits of proposed actions
S2	Low affordability of technologies by farmers due to small farm structures, low income level and knowledge	*Medium*	*Medium*	Introduce targeted financial mechanisms including subsidies and technical assistance to ensure successful introduction of technologies. Organize capacity building activities. Introduce technology transfer via establishing demonstration sites and on-job training.

Concluding remarks

Climate change impacts are on global agenda, with visible reflections in Armenia.

Agriculture sector is one of the leading and strategically important economic sectors of Armenia, which is critical from the perspective of the economic development prospects, formation of the gross domestic product, ensuring macroeconomic stability, food security and foreign trade balance.

Climate change is expected to lead to reduced crop production in the agricultural sector, deterioration of agricultural lands, increased demand for irrigation water, change in the structure of the ecosystem, emergence of new pests, diseases, safety risks, food supply and other risks.

Keeping the current trends of agriculture production and management are forecasted to boost the GHG emissions from Agriculture sector by estimated 98% by 2030 (compared to 2017), and GHG production will reach the level of 3,820 Gg CO_2 eq. This is a rather high level of GHG production which needs to be managed. Analysis of a set of scenarios and opportunities for mitigation suggests that GHG production can be reduced to the level of 28% increase by 2030 (compared to 2017) if timely and effective initiatives are undertaken.

The suggested "Mitigation" scenario considers improvements in GHG production and emissions both from livestock and crop management as compared to the "Business-as-usual" scenario.

The major sources of GHG production of livestock management are from enteric fermentation and manure management. Herein, mitigation activities include implementation of a set of best practices, including improvement in livestock health, genetics and feeding regimes. Changes in reared cattle breeds with increased meat and milk production capacities result in relatively lower animal population size. Combined use of improved animal breeds and feed quality and digestibility result in an estimated GHG production from enteric fermentation by 2030 of 1,254 Gg CO_2 eq. Additionally, introduction of AD manure management for cattle will allow GHG production of 1 Gg CH_4 and 0.22 Gg N_2O, equivalent to the 110 Gg CO_2.

The suggested mitigation scenarios are perceived to be cost effective, leading to enhanced profitability. Additionally, the farms may introduce biogas generating systems and thus apply best practices of manure management.

With regard to soils, technically, high rates of soil GHG emission reduction is possible if N is applied to the soil only in the quantities required under certain conditions ("4R Nutrient Stewardship" approach).

Success of mainstreaming climate change mitigation practices in Agriculture sector of Armenia is largely dependent on conditions, which build the basis for implementation of those measures, such as information availability, awareness, coordination and monitoring.

General measures come next such as development of a national program on climate change mitigation in agriculture sector, institutional set-up across sectoral national bodies, strengthening institutional capacities and boosting stakeholder partnerships. Finally, sector-specific measures leverage the overall efforts in climate change mitigation.

Annexes

Annex 1. Activity data for EF calculation for Swiss pure breed and mixed breed cattle

Table 29: Activity 1.1 emission factor calculation for Swiss pure breed cows, estimate, 2030

SWISS PUREBREED COWS 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Digestion index		72
Milk richness, %		4
Milk production, per head kg/days		18
CONSERVATION		
NE_m(MJ/day) = Cf_ix (Weight)$^{0.75}$	NE_m= 0.386 x 580$^{0.75}$= 0.336 x 118.2=45.6	45.6
ACTIVITY		
NE_a (MJ/day) = C_a xNEm	NE_a =0 x 118.2= 0 nursery period	0.00
	NE_a =0.36 x 45.6 = 16.4 pasture period	16.4
LACTATION		
NE_l(MJ/day) = kg milk/day x (1.47+ 0.4 x Fat)	NE_l= 18 x (1.47+ 0.4 x 4) = 55.3	55.3
GESTATION		
NE_p (MJ/day) = $C_{pregnancy}$x NE_m	NE_p = 0.1 x 45.6 = 4.56	4.56
Em/DE		
NE_m/DE = 1.123 - (4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	NE_m/DE = 1.123 - (4.092 x 0.001x 72) + [1.126 x 0.00001 x 72x72] - (25.4/72) = 0.533	0.533
GROSS ENERGY		
GE = [(NE_m+ NE_a +NE_l + NE_p) NE_{ma}/DE]/(DE/100)	GE = [(45.6+ 0 + 55.3 + 4.56+0)/0.533]/0.72= 274.8 MJ/per head/days nursery period	274.8
	GE = [(45.6+16.4 + 55.3 + 4.56+0)/0.533]/0.72= 317.5 MJ/per head/days pasture period	317.5
EMISSION FACTOR		
EF= GE x Y_mx 365 days/year)/(55.65MJ/kg CH_4)	EF= [(274.8 x 0.07x 210+317.5 x 0.06 x 155)/55.65] = 125.7 kg methane/per head/per year	125.7

Table 30: Activity 1.2 emission factor calculation for Swiss pure breed bulls

SWISS PUREBREED BULLS 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Bull weight, kg		900
Digestion index		57
CONSERVATION		
NE_m(MJ/day) = Cf_i x $(Weight)^{0.75}$	NE_m= 0.370 x $900^{0.75}$ = 0.370 x 164,3=60,79	60.79
ACTIVITY		
NE_a (MJ/day) = $C_{a\,x}$ NE_m	NE_a =0 x 60.79 = 0 nursery behavior	0.00
	NE_a =0.36 x 60.79 = 21.88 pasture behavior	21.88
NE_m/DE		
NE_m/DE = 1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE_m/DE= (1.123- (4.092 x 0.001 x 57) + (1.126 x 0.00001 x 57.0 x 57.0)-(25.4/57)= 0.4807	0.4807
GROSS ENERGY		
GE =[(NE_m+ NE_a)NE_{ma}/(DE/100)	GE =[(60.79+ 0)/0.48]/0.57= 222.18 MJ/per head/days nursery period	222.18
	GE =[(60,79+21,88)/0.48]0.57= 302.15 MJ/per head/days pasture period	302.15
EMISSION FACTOR		
EF= GE x Y_m x 365 days/year)/(55.65MJ/kg CH_4)	EF= [(222,18 x 0.07x 210+302,15 x 0.06 x 155)/55.65]= 109.18 kg methane/per head/per year	109.18

Table 31: Activity 1.3 emission factor calculation for Swiss pure-breed offspring

SWISS PUREBREED OFFSPRING 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Offspring average weight, kg		216
Offspring standard weight, kg		432 19 months)
Average daily weight gain by offspring, kg/days		0.70
Digestion energy, %		60
CONSERVATION		
NE_m(MJ/day) = Cf_ix (Weight)$^{0.75}$	NE_m= 0.322 x 216$^{0.75}$= 0.322x56.34=18.14	18.14
ACTIVITY		
NE_a(MJ/day) = C_a xNE_m	NE_a =0 x 18,14 = 0 Nursery period	0.00
	NE_a =0.70 x 18,14 = 12,69 Pasture period	12.69
GROWTH		
NE_g(MJ/day) = 4.18 x {(0.0635 x [0.891x (BW x 0.96) x (478/(C x MW)]$^{0.75}$ x (WG x 0.92)$^{1.097}$}	NE_g(MJ/day) = 4.18 x {(0.0635 x [0.891x (216 x 0.96) x (478/(1.2 x 432)]$^{0.75}$ x (0.7 x 0.92)$^{1.097}$}= 7.80	7.80
NE_{ma}/DE-REM		
NE_{ma}/DE= 1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE) REM=1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	REM = [1.123-(4.092 x 0.001x 60) + [1.126 x 0.00001 x (60 x 60)]-25.4/60)] =0.4947	0.4947
NE_g/DE-REG		
NE_g/DE= 1.164-(5.160 x 10^{-3}x DE + [1.308 x 10^{-5} x (DE)^2]-37.4/DE REG=[1.164-(5.160 x 10^{-3}x DE) + [1.308 x 10^{-5} x (DE)^2]-{37.4/DE}]	NE_g/DE= [1.164-(5.160 x 0.001x 60) + [1.308 x 0.00001 x (60 x 60)]- {37.4/60}]=0.2782	0.2782
GROSS ENERGY		
GE =[(NE_m+ NE_a)/(NE_{ma}/DE) +NE_g/ (NE_g/DE)]/(DE/100)	GE =[(18.14 + 0)/0.4947 + 7.80/0.2782]/0.60 = 107.8 MJ/per head/days pasture period	107.8
	GE= [(18,14 + 12,69) /0.4947 +(7,80/0.2782)]/0.60= 150.58 MJ/per head/days pasture period	150.58
EMMISSION FACTOR		
EF= GE x Y_mx 365 days/year)/(55.65MJ/kg CH_4)	EF= [(107.8 x 0.07x 233+150.58 x 0.06 x 132)/55.65]=53.02 kg methane/per head/per year	53.02

Annex 2. Activity data for EF calculation for Swiss crossbreed cattle

Table 32: Activity 2.1. emission factor calculation for Swiss crossbreed cows

SWISS CROSSBREED COWS 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Cow weight, kg		490
Digestion index		70
Milk richness, %		3.9
Milk production, per head kg/days		12
CONSERVATION		
NE_m(MJ/day) = Cf_ix (Weight)$^{0.75}$	NE_m= 0.386 x 490$^{0.75}$= 0.336 x 104.14 =34.99	34.99
ACTIVITY		
NE_a (MJ/day) = C_a xNEm	NE_a =0 x 118.2= 0 Nursery period	0.00
	NE_a =0.36 x 34.99 = 12.59 pasture period	12.59
LACTATION		
NE_l(MJ/day) = kg milk/day x (1.47+ 0.4 x Fat)	NE_l= 12 x (1.47+ 0.4 x 3.9) = 36.36	36.36
GESTATION		
NE_p (MJ/day) = $C_{pregnancy}$x NE_m	NE_p = 0.1 x 34.99 = 3.49	3.49
Em/DE		
NE_m/DE = 1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	NE/DE = 1.123- (4.092 x 0.001x 70) + [1.126 x 0.00001 x 70x70] -(25.4/70) = 0.529	0.529
GROSS ENERGY		
GE =[(NE_m+ NE_a +$NE_{l\,+}$ NE_p) NE_{ma}/DE]/(DE/100)	GE = [(34.99+ 0 + 36.36 $_+$ 3.49+0)/0.529]/0.70= 202.1 MJ/per head/days nursery period	202.1
	GE =[(34.99+12.59 + 36.36 + 3.49+0)/0.529]/0.70= 236.1 MJ/per head/days pasture period	236.1
EMMISSION FACTOR		
EF= GE x Y_mx 365 days/year)/(55.65MJ/kg CH_4)	EF= [(202.1 x 0.07x 210+236.1 x 0.06 x 155)/55.65] = 92.8 kg methane/per head/per year	92.8

Table 33: Activity 2.1. emission factor calculation for Swiss crossbreed bulls

SWISS MIXED- BREED GROWING CATTLE 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Bull weight, kg		714
Digestion index		57
CONSERVATION		
NE_m(MJ/day) = Cf_i x $(Weight)^{0.75}$	NE_m= 0.370 x $714^{0.75}$ = 0.370 x138.12= =51.10	51.10
ACTIVITY		
NE_a (MJ/day) = $C_{a\ x}$ NE_m	NE_a =0 x 51.10= 0 Nursery period	0.00
	NE_a =0.36 x 51.10 = 18.39 Pasture period	18.39
$NE_{m/}DE$		
NE_m/DE = 1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x $(DE)^2$]-25.4/DE)	NE/DE= (1.123- (4.092 x 0.001 x 57) + (1.126 x 0.00001 x 57 x 57)-(25.4/57)= 0.4807	0.4807
GROSS ENERGY		
GE =[(NE_m+ NE_a)NE_{ma}/(DE/100)	GE =[(51.10+ 0)/0.48]/0.57= 186.76 MJ/per head/days nursery period	186.76
	GE = [(51.10+18,39)/0.48]/0.57= 253.98 MJ/per head/days pasture period	253.98
EMISSION FACTOR		
EF= GE x Y_m x 365 days/year)/(55.65MJ/kg CH_4)	EF= [(186.76 x 0.07x 210+253.98 x 0.06 x 155)/55.65] = 92.27 kg methane/per head/per year	92.27

Table 34: Activity 2.1. emission factor calculation for Swiss crossbreed offspring

SWISS MIXED- BREED OFFSPRING 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
Offspring average weight, kg		164
Offspring standard weight, kg		322 (19 months)
Average daily weight gain by offspring, kg/days		0.47
Digestion energy, %		60
CONSERVATION		
NE_m(MJ/day) = Cf_ix (Weight)$^{0.75}$	NE_m= 0.322 x 164$^{0.75}$= 0.322x45.83=14.75	14.75
ACTIVITY		
NE_a(MJ/day) = C_a xNE_m	NE_a =0 x 14.75 = 0 Nursery period	0.0000
	NE_a =0.47 x 14.75 = 6.93 Pasture period	6.93
GROWTH		
NE_g(MJ/day) = 4.18 x {(0.0635 x [0.891x (BW x 0.96) x (478/(C x MW)]$^{0.75}$ x (WG x 0.92)$^{1.097}$}	NE_g(MJ/day) = 4.18 x {(0.0635 x [0.891x (164 x 0.96) x (478/(1.2 x 322)]$^{0.75}$ x (0.47 x 0.92)$^{1.097}$}= 5.0615 NE_g(MJ/day) = 4.18 x {(0.0635 x [0.891x (157.44) x (1.238)]$^{0.75}$ x (0.4324)$^{1.097}$}= 5.0615 NE_g(MJ/day) = 4.18 x {(0.0635 x [173.67]$^{0.75}$ x (0.4324)$^{1.097}$}= 5.0615 NE_g(MJ/day) = 4.18 x {0.0635 x 47.84 x 0.3986}= 5.0615	5.0615
NE_{ma}/DE-REM		
NE_{ma}/DE= 1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE) REM=1.123-(4.092 x 10^{-3}x DE + [1.126 x 10^{-5} x (DE)^2]-25.4/DE)	REM = [1.123-(4.092 x 0.001x 60) + [1.126 x 0.00001 x (60 x 60)]-25.4/60)]=0.4947 REM = [1.123-(0.2455) + [(0.0405)]-(0.4233)]=0.4947	0.4947
NE_g/DE-REG		
NE_g/DE= 1.164-(5.160 x 10^{-3}x DE + [1.308 x 10^{-5} x (DE)^2]-37.4/DE REG=[1.164-(5.160 x 10^{-3}x DE) + [1.308 x 10^{-5} x (DE)^2]-{37.4/DE}]	NE_g/DE= [1.164-(5.160 x 0.001x 60) + [1.308 x 0.00001 x (60 x 60)]- {37.4/60}]=0.2782	0.2782

SWISS MIXED- BREED OFFSPRING 2030		
INPUT DATA	**CALCULATIONS**	**RESULTS**
GROSS ENERGY		
GE =[(NE_m+ NE_a)/(NE_{ma}/DE) +NE_g/ (NE_g/DE)]/(DE/100)	GE =[(14.75 + 0)/0.4947 + 5.0615/0.2782]/0.60 = 80.0 MJ/per head/days nursery period	80.0
	GE= [(14.75 + 6.93)/0.4947 + (5.0615/0.2782)]/0.60=103.36 MJ/per head/days pasture period	103.36
EMISSION FACTOR		
EF= GE x Y_mx 365 days/year)/(55.65MJ/kg CH_4)	EF= [(80.0 x 0.07x 233+103.36 x 0.06 x 132)/55.65]= 38.16 kg methane/per head/per year ---------------------------------- EF= [80x(6.5:100)x210/55.65]= 19.62 kg methane/per head/ /210 days nursery period EF=[103.36x(6.5:100)x155/55.65]=18.71 kg methane/per head /155 days pasture period Σ EF_{365day}=38.33 kg CH_4	38.16 --------------- 38.33

Annex 3. Analysis of cost-effectiveness for importing Swiss breed cows and improving the breed type through artificial insemination and crossbreeding, 2021-2030

QUANTITATIVE ANALYSIS	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
CAPITAL COSTS											
Purchase of swiss pure breed -1*2400 EUR	1,536,000										1,536,000
	-	-	-	-	-	-	-	-	-	-	-
TOTAL CAPITAL COSTS	1,536,000	-	-	-	-	-	-	-	-	-	1,536,000
VARIABLE COSTS											
Number of Cows Swiss	1	1	1	1	1	1	1	1	1	1	1
In farm keeping (wintering) period 210 days											
Rough feed- grass- self-produced	57,750	57,750	57,750	57,750	57,750	57,750	57,750	57,750	57,750	57,750	577,500
Juicy (wet) feed - silage self-produced	78,750	78,750	78,750	78,750	78,750	78,750	78,750	78,750	78,750	78,750	787,500
Juicy (wet) feed - fodder beet purchased	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	42,000	420,000
Combined feed - purchased	189,000	189,000	189,000	189,000	189,000	189,000	189,000	189,000	189,000	189,000	1,890,000
Pasturing period 155 days											-
Pasture green – cost per 1 cow per day	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	405,000
Combined feed - purchased	83,700	83,700	83,700	83,700	83,700	83,700	83,700	83,700	83,700	83,700	837,000
SUBTOTAL VARIABLE FEEDING COSTS-SWISS COW	491,700	491,700	491,700	491,700	491,700	491,700	491,700	491,700	491,700	491,700	4,917,000
Number of Cows Cross Breed	5	5	5	5	5	5	5	5	5	5	5
In farm keeping (wintering) period 210 days											
Rough feed- grass- self-produced	262,500	262,500	262,500	262,500	262,500	262,500	262,500	262,500	262,500	262,500	2,625,000
Juicy (wet) feed - silage self-produced	315,000	315,000	315,000	315,000	315,000	315,000	315,000	315,000	315,000	315,000	3,150,000
Juicy (wet) feed - fodder beet purchased	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	210,000	2,100,000
Combined feed - purchased	661,500	661,500	661,500	661,500	661,500	661,500	661,500	661,500	661,500	661,500	6,615,000
Pasturing period 155 days											-
Pasture green – cost per 1 cow per day	202,500	202,500	202,500	202,500	202,500	202,500	202,500	202,500	202,500	202,500	2,025,000
Combined feed - purchased	279,000	279,000	279,000	279,000	279,000	279,000	279,000	279,000	279,000	279,000	2,790,000
SUBTOTAL VARIABLE FEEDING COSTS-MIXED COWS	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	1,930,500	19,305,000
Number of Swiss calves	0							1	1		0
Rough feed- grass- self-produced	-	-	-	-	-	-	-	46,903	46,903	-	93,805
Juicy (wet) feed - silage self-produced	-	-	-	-	-	-	-	78,019	78,019	-	156,038
Combined feed - purchased	-	-	-	-	-	-	-	93,951	93,951	-	187,902
SUBTOTAL VARIABLE FEEDING COSTS-SWISS CALVE	-	-	-	-	-	-	-	218,872	218,872	-	437,745
Number of mixed breed calves							2	5	3	0	0
Rough feed- grass- self-produced	-	-	-	-	-	-	85,410	213,525	128,115	-	427,050
Juicy (wet) feed - silage self-produced	-	-	-	-	-	-	142,350	355,875	213,525	-	711,750

Combined feed - purchased	-	-	-	-	-	-	170,820	427,050	256,230	-	854,100
SUBTOTAL VARIABLE FEEDING COSTS-MIXED CALVES	-	-	-	-	-	-	398,580	996,450	597,870	-	1,992,900
TOTAL VARIABLE FEEDING COSTS	2,422,200	2,422,200	2,422,200	2,422,200	2,422,200	2,422,200	2,820,780	3,637,522	3,238,942	2,422,200	26,652,645
OTHER VARIABLE COSTS	1,038,086	1,038,086	1,038,086	1,038,086	1,038,086	1,038,086	1,208,906	1,558,938	1,388,118	1,038,086	11,422,562
TOTAL COSTS	4,996,286	3,460,286	3,460,286	3,460,286	3,460,286	3,460,286	4,029,686	5,196,460	4,627,060	3,460,286	39,611,206
QUANTITATIVE BENEFITS	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**TOTAL**
REVENUES											
Sales of milk 18liters daily/ 195 AMD per 1 liter/ Swiss breed	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	1,070,550	10,705,500
Sales of milk 12.8liters daily/ 195AMD per 1 liter/ Mixed breed	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	3,806,400	38,064,000
Sales of calves 1Swiss-80,000 AMD, 1mixed breed-50,000 AMD	380,000	330,000	330,000	330,000	330,000	330,000	150,000	180,000	330,000	330,000	3,020,000
Sales of cows 1 Swiss-638,000 AMD, 1mixed breed-539,000 AMD									638,000	2,695,000	3,333,000
TOTAL REVENUES	5,256,950	5,206,950	5,206,950	5,206,950	5,206,950	5,206,950	5,026,950	5,056,950	5,844,950	7,901,950	55,122,500
NET PROFIT OR LOSS	260,664	1,746,664	1,746,664	1,746,664	1,746,664	1,746,664	997,264	(139,510)	1,217,890	4,441,664	15,511,294
CUMULATIVE NET CASH FLOW	260,664	2,007,329	3,753,993	5,500,657	7,247,321	8,993,986	9,991,250	9,851,740	11,069,629	15,511,294	

Annex 4: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 3 or manure production of 120 kg (calculated with fertilizers), 2021-2030

QUANTITATIVE ANALYSIS	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
CAPITAL COSTS											
Biogas reactor purchase, 4,000 EUR	(2,560,000)										(2,560,000)
TOTAL CAPITAL COSTS	(2,560,000)	-	-	-	-	-	-	-	-	-	(2,560,000)
VARIABLE COSTS											
Maintenance Cost per year 90 EUR		(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(518,400)
TOTAL VARIABLE FEEDING COSTS	-	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(518,400)
OTHER VARIABLE COSTS	-										-
TOTAL COSTS	(2,560,000)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(3,078,400)
QUANTITATIVE BENEFITS	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
REVENUES/Annual											
Manure		36,765	36,765	36,765	36,765	36,765	36,765	36,765	36,765	36,765	330,882
Biogas/m3 - from 120 kg of manure 10 m^3 of biogas		3,064	3,064	3,064	3,064	3,064	3,064	3,064	3,064	3,064	27,573
Fertilizer- from 120 kg manure 13.5 kg of fertilizer		4,136	4,136	4,136	4,136	4,136	4,136	4,136	4,136	4,136	37,224
Income from biogas 1 m3=100 AMD		306,372	306,372	306,372	306,372	306,372	306,372	306,372	306,372	306,372	2,757,347
Income from fertilizer 1kg=100 AMD		413,602	413,602	413,602	413,602	413,602	413,602	413,602	413,602	413,602	3,722,418
TOTAL REVENUE	-	719,974	719,974	719,974	719,974	719,974	719,974	719,974	719,974	719,974	6,479,765
COST SAVINGS											
Utility cost savings		95,040	95,040	95,040	95,040	95,040	95,040	95,040	95,040	95,040	855,360
TOTAL COST SAVINGS	-	95,040	95,040	95,040	95,040	95,040	95,040	95,040	95,040	95,040	855,360
TOTAL BENEFITS	-	815,014	815,014	815,014	815,014	815,014	815,014	815,014	815,014	815,014	7,335,125

NET PROFIT OR LOSS	(2,560,000)	757,414	757,414	757,414	757,414	757,414	757,414	757,414	757,414	757,414	4,256,725
Interest rate	10%										
Interest rate	5%										
PV at 10%	**(2,560,000)**	**688,558**	**625,962**	**569,056**	**517,324**	**470,294**	**427,540**	**388,673**	**353,339**	**321,217**	**1,801,965**
PV at 5%	**(2,560,000)**	**721,347**	**686,997**	**654,283**	**623,126**	**593,454**	**565,194**	**538,280**	**512,648**	**488,236**	**2,823,563**

NPV at 10%=1,801,965
NPV at 5%=2,823,563

Annex 5: Analysis of cost effectiveness for introducing biogas reactor in a farm with a headcount of 13 or manure production of 308 kg (calculated with fertilizers), 2021-2030

QUANTITATIVE ANALYSIS	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	TOTAL
CAPITAL COSTS	0	1	2	3	4	5	6	7	8	9	
Purchase of biogas reactor, 2*4,000 EUR				(5,120,000)							(5,120,000)
TOTAL CAPITAL COSTS	-	-	-	(5,120,000)	-	-	-	-	-	-	(5,120,000)
VARIABLE COSTS											
Maintenance cost, 90EUR				(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(403,200)
TOTAL VARIABLE FEEDING COSTS	-	-	-	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(403,200)
OTHER VARIABLE COSTS	-	-	-	-	-	-	-	-	-	-	-
TOTAL COSTS	-	-	-	(5,177,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(57,600)	(5,523,200)
QUANTITATIVE BENEFITS	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**TOTAL**
REVENUES											
Manure, annual/ kg				88,812	88,812	88,812	88,812	88,812	88,812	88,812	621,683
Biogas Produced, 10m^3 from 120kg manure		-	-	7,401	7,401	7,401	7,401	7,401	7,401	7,401	51,807

Annual Fertilizer Produced, 13.5kg fertilizer from 120kg manure		-	-	9,991	9,991	9,991	9,991	9,991	9,991	9,991	69,939
Revenue from Biogas, 1m3 100 AMD		-	-	740,098	740,098	740,098	740,098	740,098	740,098	740,098	5,180,688
Revenue from Fertilizer, 1kg 100 AMD		-	-	999,133	999,133	999,133	999,133	999,133	999,133	999,133	6,993,929
TOTAL REVENUE	-	-	-	1,739,231	1,739,231	1,739,231	1,739,231	1,739,231	1,739,231	1,739,231	12,174,618
COST SAVINGS											
Utility Cost Savings				95,040	95,040	95,040	95,040	95,040	95,040	95,040	665,280
TOTAL COST SAVINGS	-	-	-	95,040	95,040	95,040	95,040	95,040	95,040	95,040	665,280
TOTAL BENEFITS	-	-	-	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	1,834,271	12,839,898
NET PROFIT OR LOSS	-	-	-	(3,343,329)	1,776,671	1,776,671	1,776,671	1,776,671	1,776,671	1,776,671	7,316,698
Interest rate	10%										
Interest rate	5%										
PV at 10%	**-**	**-**	**-**	**(2,511,892)**	**1,213,490**	**1,103,173**	**1,002,885**	**911,713**	**828,830**	**753,482**	**3,301,681**
PV at 5%	**-**	**-**	**-**	**(2,888,093)**	**1,461,672**	**1,392,068**	**1,325,779**	**1,262,647**	**1,202,521**	**1,145,258**	**4,901,852**

NPV at 10%=3,301,681
NPV at 5%=4,901,852

Annex 6: EU practice and regulations to reduce GHG emissions from the agriculture

Overview

GHG emissions is one of the most pressing challenges of today's world. It has been causing the atmosphere to heat up and the climate to change on annual basis. As a result, animal species are at the risk of extinction, and forests and oceans are being polluted and destroyed.[116]

EU is one of the largest contributors to GHG emissions*.** In 2019, the GHG emissions generated by households ***and economic sector amounted in 3.8 billion tons of CO_2 equivalent[117]. This is a 24% decrease from year 1990, which is 4% higher than the targeted level. At the same period, the economy in EU grew by 61%.[118]

Thus, EU is considered to be making a good progress on tackling climate change, by both modernizing its economy and reducing its emissions. However, there is still much work which should be done. Agricultural land comprises 40% of the EU territory and as described earlier in this report, it is a large source of GHG emissions. 10% of the GHG emissions in EU are attributable to this sector.[119] The effective reduction of the emissions is to a large extent reliant on a successful implementation of the key policies and regulations, as the EU is the only major economy of the world to have put in place legislation covering all sectors of the economy to cut GHG emissions.[120]

This chapter will examine the regulations and best practice examples in EU region, which are targeted at reducing GHG emissions.

6.1 Policy, legal and regulatory framework to address GHG emissions in the EU

International policies play a key role in highlighting the importance of adapting to climate change in the agriculture sector at a global level. In Europe, the EU adaptation strategy and the common agricultural policy offer opportunities for the EU agriculture sector to adapt to climate change; however, the ambition varies by EU member states. There are a number of EU global and local level policies and tools addressing the impact of climate change mitigation on agricultural production or its support to adapt those various measures for mitigation in the sector. In agriculture sector, the EU policy framework on global level of climate change mitigation includes:

- The Kyoto Protocol,
- The Paris Agreement,
- Common Agriculture Policy (CAP),
- The EU strategy on adaptation to climate change, which leads to climate change mitigation and the final output of the strategy adaptation is to bring reduction of GHG emissions,
- other EU level directives such as Water Framework directive, EU Floods Directive, which are also developed for climate change adaptation and mitigation of GHG emission.

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[117] Greenhouse gas emission statistics - air emissions accounts, The European Commission, 2021. Link: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/30599.pdf
[118] Total greenhouse gas emission trends and projections in Europe, The European Commission, 2021. Link: https://www.eea.europa.eu/data-and-maps/indicators/greenhouse-gas-emission-trends-7/assessment
[119] "Climate change adaptation in the agriculture sector in Europe", EEA report, 2019
[120] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

At a global level, polices play an important role in emphasizing the need to adapt climate change mitigation measures in agriculture sector worldwide. Those measures have been designed to strengthen the capacity of all countries to deal with climate change wisely and in a literate manner, with the final aim of increasing the awareness, resilience and reducing risks[121].The EU strategy on adaptation to climate change and Common Agricultural Policies enable those opportunities for climate change adaptation.

Global EU policies to address GHG emissions

Kyoto Protocol and Paris Agreement

In 1992, the global nations signed the United Nations Framework Convention on Climate Change (UNFCCC), to stabilize GHG emissions. Later, in 1997 with the ***Kyoto Protocol***, developing countries also became part of the measures for emission reduction initiative. As part of the Kyoto Protocol, the developed countries also devoted to support in achievement of the emission reduction targets in a sustainable way. Nowadays, all the procedures are monitored by UNFCCC Secretariat and the execution done by Kyoto Protocol.

The Paris Agreement was signed by 197 countries in 2015. The purpose of the agreement is to set limitations in the rise of global average temperatures from below for the pre-industrial level to well-below 2° C above pre-industrial levels.

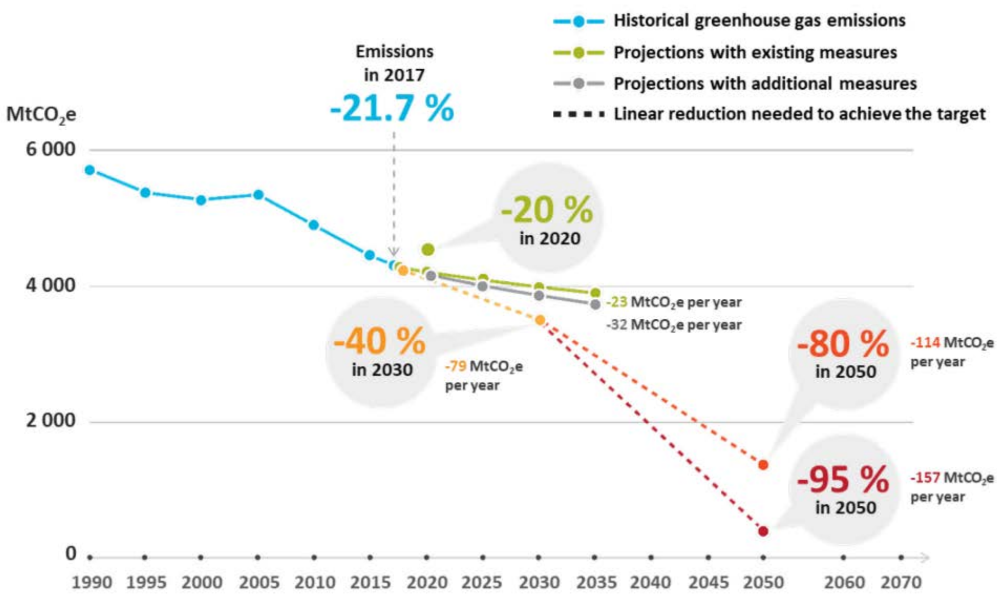
Framework of Kyoto Protocol is valid until the reporting of emissions for 2020 which is going to be reported and published in 2022. In case of Paris Agreement framework, emissions for year 2021 will be initially reported which will be published in 2023. It is done to assure the high quality of the procedures followed under the framework. The results should be provided to UNFCCC Secretariat and expert team and supported by the guidelines established by UNFCCC and the International Panel for Climate Change.

The next Figure shows GHG emission trends stating from 1990 until 2050 taking into account existing and additional measures for the mitigation. EU has undertaken to reduce its GHG emissions by 40% by 2030 and by 80% to 95% in 2050. In 2017, the EU reduced its emissions by 21.7 % on 1990 levels.[122]

[121] Climate Change adaptation in the Agriculture sector in Europe, European Environment Agency, 2019.
Link: https://www.euroseeds.eu/app/uploads/2019/09/Climate-change-adaptation-in-the-agriculture-sector-in-Europe.pdf#page=26&zoom=100,0,0

[122] European court of Auditors, "EU greenhouse gas emissions: Well reported, but better insight needed into future reductions, 2019.
Link: https://www.eca.europa.eu/Lists/ECADocuments/SR19_18/SR_Greenhouse_gas_emissions_EN.pdf

Figure 18: EU greenhouse gas emission trends and forecasts from 1990 until 2050



Source: European Court of Auditors, based on EU Inventory Report of 2019 (2017 emission data), the 2017 EU National Communication and Biennial Report to the UNFCCC (projections data) and the EEA “Trends and projections in Europe 2018 – Tracking progress towards Europe’s climate and energy targets” (yearly reductions needed to achieve the targets).

The reduction of most of the GHG followed this downward trend under Kyoto Protocol.

Another important component of the Kyoto Protocol is the market mechanism established on the trade of emission permits. According to the Protocol each country should meet the mentioned targets by the national measures. [123]

The Protocol offers additional solutions of three market-based mechanisms:

- ***International Emissions Trading***: under Article 17 of Kyoto Protocol countries that have emission units to spare can sell their additional capacity to countries that are over their targets[124],
- ***Clean Development Mechanism (CDM):*** Article 12 of the Protocol allows a country with an emission-reduction or emission-limitation to implement an emission-reduction project in developing countries. It gives additional emission reduction credits for meeting the Kyoto Protocol goals. [125],
- ***Joint implementation (JI):*** under Article 6 of the Kyoto Protocol, a country with an emission reduction or limitation commitment under the Kyoto Protocol is allowed to earn emission reduction units (ERUs) from an emission-reduction or emission removal project of another party.[126]

All above mentioned mechanisms and measures are monitored, reviewed and verified under the monitoring system which is development by The Kyoto Protocol. [127]

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[123] UN Climate Change, Process and meetings, Kyoto Protocol, 2021
Link: https://unfccc.int/kyoto_protocol

[124] UN Climate Change, Process and meetings, Emissions Trading, 2021
Link: https://unfccc.int/process/the-kyoto-protocol/mechanisms/emissions-trading

[125] UN Climate Change, Process and meetings, The Clean Development Mechanism, 2021
Link: https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism

[126] UN Climate Change, Process and meetings, Joint implementation, 2021
Link: https://unfccc.int/process/the-kyoto-protocol/mechanisms/joint-implementation

[127] UN Climate Change, Process and meetings, Kyoto Protocol, 2021. Link: https://unfccc.int/kyoto_protocol

National EU policies to address GHG emissions

The policy framework sections described above were part of Global EU policy. However, as mentioned earlier, the EU agriculture sector is regulated by a ***Common Agricultural Policy (CAP).*** Under the CAP, local EU national policies and EU adaptation strategy are considered. EU adaptation strategy is aimed at reducing (bring it to zero emission) GHG emissions by 2050 through CAPs measures. The latter was approved in 2013 and evaluated in 2018. It plays a key role in adaptation strategy. Since, the agriculture sector is still most sensitive and vulnerable to climate change and its impact is tangible, EU Member States have developed National Adaptation Strategy to minimize risks on national level. The common agricultural policy provides a financial framework for financing adaptation at regional and farm levels, which brings a positive effect on mitigation and biodiversity. Some measures which lead to high effectiveness of mitigation on farm level include:

- ✓ adapted crops,
- ✓ use of cover crops and artificial soil covers,
- ✓ crop diversification and rotation,
- ✓ no tillage and minimum tillage,
- ✓ adapted timing of sowing and harvesting,
- ✓ precision farming,
- ✓ improved irrigation efficiency,
- ✓ livestock breeding,
- ✓ improved posture management,
- ✓ improved livestock rearing conditions,
- ✓ organic farming, farm production and income diversification.

The new proposed CAP for 2021-2027 has adaptation for GHG emission mitigation as a clear objective, which could lead to EU Member States having to increase their financing of adaptation measures in the sector.[128] Under the CAP, regional rural development programmes are being developed which serve as the main source of financing and promoting measures for climate change adaptation in Agriculture sector. These programmes enable to mainstream the climate change policies into sectoral ones. In Europe, the European Agricultural Fund for Rural Development (EAFRD) has played an important role in co-financing such activities.

Climate change mitigation is directly linked to EU Adaptation Strategy. In line with Paris Agreement, it has long-term vision to make EU more resilient to climate change impacts by 2050- with zero emissions by 2050. It follows three objectives with their corresponding action plans:

- ➢ Smarter Adaptation through knowledge improvement,
- ➢ Systemic Adaptation through policy improvement
- ➢ Faster Adaptation through quick response for implementation.

To narrow the adaptation strategy to the agricultural sector, the Food and Agriculture Organization of the United Nations (FAO) provides technical capacity and financial assistance, in particular to the least developed countries. The FAO provides indicators to measure the distances to the targets for achieving the Sustainable Development Goals and agreed targets to reduce the risk of disasters in the global agriculture sector. Between 2011 and 2016, the FAO established "FAO-Adapt: framework programme on climate change adaptation" as a response to the global call for measures to tackle climate change through adaptation. As a

[128] https://www.euroseeds.eu/app/uploads/2019/09/Climate-change-adaptation-in-the-agriculture-sector-in-Europe.pdf#page=26&zoom=100,0,0

framework programme for climate change adaptation, "FAO-Adapt" promoted activities in agriculture, forestry and fisheries that can lead to sustainable production increases while promoting resilience to the current and future impacts of climate change. [129]

The European Green Deal and Farm to Fork Strategies

The above-mentioned challenges are overseen by The European Green Deal - which represents a set of policy initiatives designed by the European Commission.

Figure 19: Illustration of the various elements of the Green Deal

Source: The European Green Deal (European Commission 2019).

It is a new growth strategy that aims to transform the EU society to a better modern, resource-efficient and competitive economy where there are no net GHG emissions by 2050 and economic growth is separated from resource use. In the framework of the European Green Deal, in September 2020 the Commission proposed to increase the 2030 GHG emission reduction target, including emissions and removals, by at least 55% compared to 1990. It examined the actions required in all areas, including energy efficiency and increasing renewable energy, started the process of submitting detailed legislative proposals to bring to life the extended ambitions by June 2021. The 2030 climate and energy framework include EU-wide targets and policy goals for the period 2021-2030.[130]

The Farm to Fork strategic plan aims to reduce the use and risk of chemical pesticides, as well as the use of fertilizers and antibiotics in food value chains. The EU directive will define necessary measures, including legislative, to bring about these reductions based on a stakeholder dialogue level. It has also the aim to increase organically cultivated areas in Europe. According to new measures which will be defined, the EU should give various innovative ways to protect harvests from pests and diseases. New innovative techniques will assure improvement of sustainable food system and the safety of it. The Farm to Fork Strategy will also contribute to economic development of the countries in the particular sphere, as it will reduce the environmental impact of the food processing and retail sectors by taking action on transport, storage, packaging and food waste. Last of all, the Farm to Fork Strategy will guarantee sustainable and affordable food consumption and promote healthy food access for all. It will be done by giving access to better information to consumers through digital means and detailed information about any food, for example, on details such as where the food comes from, its nutritional value, and its environmental footprint. The Farm to Fork strategy will also cover the position of farmers in the value chain by supporting them.[131]

[129] https://climate-adapt.eea.europa.eu/about

[130] Communication from the commission, The European Green Deal
Link: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1596443911913&uri=CELEX:52019DC0640#document2

[131] "Communication on The European Green Deal", European Commission, 2019
Link: https://ec.europa.eu/info/publications/communication-european-green-deal_en

6.2 Best practice review: measures in mitigation

As described previously, each Member State has its own regulations and measures which it follows and reports. However, all the measures, which result in reduction of emissions in agriculture sector are somehow connected and approved by the CAP. This Chapter examines the best practice examples, based on already registered methane and nitrous emissions.

According to the latest available data, for the period 1990-2015, in EU-28 methane emission decreased by 21%. The main reason of the reduction was the fall of animal heads, mainly ruminant livestock. For the period of 1990-2015, the number of cattle decreased by 26%. The reduction of CH4 from agriculture sector was registered almost in all EU-28 countries between 1990 to 2015. For example, Bulgaria registered a 70% reduction and Slovakia - 64%, which showed the largest proportional decreases during that period.

Another largest emission comes from nitrous oxide emissions from agricultural soils. Between 1990 to 2015, emissions from nitrous oxide decreased by 17%. The reason for lower emission was lower level of usage of nitrogen fertilizer on farmland mainly, in all EU-28 countries. In some Member States, reductions were significant. For example, in Slovakia, 47% reduction of nitrous emission was reported, in the Czech Republic - 46%, in Romania - 45% and in Estonia - 44%.[132]

Best practice: Bulgaria

Bulgaria has a small contribution to the overall GHG emissions in EU. The latest available inventory for Bulgaria report that the country had an overall contribution to methane and nitrous oxide emissions in Europe equal to 1.4%.[133] According to "Climate change adaptation in the agriculture sector in Europe" by EEA, Bulgaria has conducted CCIV assessments and designed specific adaptation measures for agriculture sector. It is one of the most successful countries in Europe to implement emission reduction measures in agriculture sector, which are described next.

In Bulgaria, measures are taken so that its indicators will reach mitigation trend to target the Kyoto Protocol. Some of the measures include:

Measure: encouraging the use of suitable crop rotation**,** especially with nitrogen fixing crops, which is a potential tool for reducing GHG. This measure covers: 20,000 ha, of which 60% is in organic production. The measure of the crop rotation is expected to result in a total reduction of 6,356 Gg CO2 eq.

Measure: management of degraded agricultural land through:

1. biological reclamation with typical for the region grass species
2. implementation of erosion control measures and soil treatment methods.

The erosion of the soil is critical in the country, more than 60% is affected. The main erosion comes from water and wind. So, the management of irrigation water controls the stocks of organic carbon and their distribution on the landscape. This affects the circulation of carbon, the content of carbon dioxide in the atmosphere and climate warming. This measure is expected to have resulted in total reduction of 20,000 tonnes CO2 eq. by 2020.

[132] "Agri-environmental indicator – greenhouse gas emissions", European Commission, 2017
Link: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/16817.pdf
[133] Ibid

Measure: improving the knowledge of farmers regarding humus conservation activities (fertilization - precise fertilization, green manure, liming, soil cultivation, prevention of stubble burning, anti-erosion measures, etc.). Knowledge improvement through advice and training played an essential role for farmers. For example, the knowledge about the most appropriate methods of tillage improved the humus layer which reduced the number of soil treatments. Overall, there are 5,000 trained farmers by 2020.

Measure: improvement of the manure management. The storing and handling activities were taking into practice both for solid and liquid manure and use of its tools for processing and storing. This is expected to have resulted in a total reduction of 1,171 tonnes CO2 eq. by 2020.

Measure: financial support for improving the equipment and the technology of production. In rice production, the low carbon technologies and methods were introduced. The expected reduction of emissions is 10 tonnes CO2 eq. by 2020[134].

Best practice: Estonia

Estonia contributes to 0.3% of the total GHG emissions from Agriculture sector in Europe. In Estonia, the area under organic cultivation has increased during last years - by 40%, along with the number of processors and distributors. In parallel, the number of organic livestock, especially sheep, has also increased. The total GHG emissions reported in the Agricultural sector of Estonia were 1,337.6 kt CO2 eq. in 2015. The sector contributed about 7.4% to the total CO2 eq. emissions in Estonia. In 2015, the emissions from enteric fermentation decreased by 3.5% and from manure management.

Regarding GHG emissions, a number of measures have been implemented.

Measure: construction or reconstruction of new livestock facilities (incl. manure and silage storage facilities) in order to prevent the environmental risks arising from production. It is done also to make farms more environmentally friendly and sustainable.

Measure: use of local varieties of crop. Helps to reduce use of chemicals and additional treatments, as local varieties are more resistant to weed, pests and climatic conditions.

Measure: limitation of the nutrient leaching from crop and keeping organic matter in the soil. The objective is to make farms with monocultures more environmentally friendly and sustainable[135].

Best practice: Belgium

Belgium contributes to 2.3% emissions of nitrous oxide and methane in Europe. The reduction of GHG emissions in agriculture sector between 1990 and 2016 was 19.5% or 2,390.75 kt CO2 eq. The change was mainly achieved through ***decrease in enteric fermentation from reduction in livestock heads*** (dairy cattle), and by reduction of nitrogen fertilizers application.[136]

The agriculture land covers the greater part of the country (44%) and it contributes to 2.3% emissions of nitrous oxide and methane in Europe. In Belgium, 8.5% of GHG emissions accounted from the agriculture

[134] https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/274195_Bulgaria-BR3-NC7-1-VII_NC_Bulgaria_2018.pdf

[135] https://unfccc.int/files/national_reports/annex_i_natcom_/application/pdf/37608415_estonia-nc7-1-nc7_est_30122017.pdf

[136] "Belgium's seventh national communication and third biennial report on climate change", National Climate Commission under UNFCCC, 2017.
Link: https://unfccc.int/sites/default/files/resource/7319685_Belgium-NC7-BR3-1-NC7_EN_LR.pdf

sector excluded the use of fuel. For the period of 1990 to 2015, in the agriculture sector, total GHG emission decreased by 21.3%. 45% of this emission were generated from enteric fermentation in 2013. It is mainly due to livestock reduction, as well as from the shift from dairy cattle to brood cattle. This leads to smaller emissions and is due to the shift in general EU trend linked to Common Agriculture Policy (CAP).

The second largest emission accounted from manure management 20% in 2015. Swine manure formed the main part of the emissions, 58%. The same measure under the CAP mentioned above is considered to lower the emission impact. The rest of 35% of total emission in agriculture emission originated from N2O emissions in the soil. Between 1990 to 2015, it decreased by 24%. Reasons for reduction include use of small quantities of fertilizers and also reduction of livestock number, which led to nitrogen extraction on pasture. In addition, organic farming has been taking over quickly in terms of surface of land and number of farms, having increased by 9.1% between 2010 and 2016. The number of certified organic cattle has also been increasing.

Best practice: Latvia

Latvia’s share in EU agriculture sector GHG emissions equals to 0.6%. Main mitigation measures include:

- ***good agriculture practice provision which includes crop fertilization plans,***
- ***management of nitrate use at vulnerable territories,***
- ***improvement of manure management systems,***
- ***manure spreading requirements and integrated farming through introduction of leguminous plants on arable lands,***
- ***organic farming,***
- ***production of biogas as an economic measurement driven by CAP.***

As a result of those measures, there is optimum crop fertilization, increased crop growth and yield which leads to reduction of unabsorbed N. Moreover, in Latvia, if the agricultural land is located in vulnerable areas and is larger than 20 ha or farmer grows vegetables, potatoes, fruit trees or fruit bushes in an area of 3 ha and more in vulnerable territories, then fertilization plan in those farms should be prepared based on N content in manure for expected yield. The limit of usage is 170 kg of nitrogen from manure and digesters per hectare.

Measure: renovation and improvement of manure management and its storing system in environmentally friendly way. This requirement refers to farms with more than 10 animal units and in vulnerable territories with 5 animal units.

Measure: in case of organic farming, the measures which brought to reduction of nitrates were methods such as ***improvement of cropland management and reduction of synthetic fertilizers***. It minimizes the amount of nitrate leach. Organic farms get support from the state through subsidies.

Measure: promotion of bioresources use to produce biogas. The implementation of this technology allows manure to be used efficiently. In agriculture, an anaerobic digester can be built to serve one single farm or collect waste from neighboring farms. The technology may differ from farm to farm and it depends on the type of manure on the farm, climate zone, investment opportunities and existing equipment.[137]

[137] “Latvia’s seventh national communication and third biennial report”, under UNFCCC, 2017.
Link: https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/934015_Latvia-NC7-BR3-1-LATVIA_NC7_29122017.pdf

Best practice: Czech Republic

The Czech Republic has contributed to 1.9% of GHG emissions in Europe. It has approximately 7.9 million ha territory and the agricultural / farming land took up 53.4% in 2015 (in 2003 it was 54.1%). The number of organic farms has been steadily growing in the recent years. Numbers of distributors and producers of bio food have also been growing.

"In 2015, the CH4, N2O and CO2 emissions reached the total of 8483 Gg (kt) CO2 eq. N_2O emissions in agricultural sector. This represented 73.1% of total N2O emissions in the Czech Republic"[138]. The observation of fertilizer application among EU countries has indicated that Czech Republic has most commonly a lower level of fertilizer application in comparison with other EU countries.

Measure: Since 1990, the decrease of methane emissions for enteric fermentation and manure management is connected to the ***decrease in the numbers of cattle and swine.*** It seems that agrarian conditions have, at least in part, settled down to the current level. The reduction in the dairy cow population is partly counterbalanced by an increase in dairy cow efficiency (increasing gross energy intake and milk production).[139]

Best practice: New Zealand

In addition to the review of the best practices applicable to EU countries, the practices and measures in New Zealand have been examined. New Zealand serves as an example of a progressive country which utilizes different tools to mitigate the climate change impacts in agriculture sector and to prepare for its adaptation. In New Zealand, Government acts as an active implementer of the measures to reduce GHG emissions, at the farmer level, or more specifically, at individual level. Those measures include:

Measure: improving forage quality

Forage processing can effectively improve digestibility of the diet and improve animal productivity at the same time. Moreover, grazing management and improving forage quality by changing forage species can equally contribute to a proper diet formulation in extensive system. Reductions in emissions intensity of 30% are considered possible in systems that currently use very low-quality feed.

Measure: dietary improvements and substitutes

Feed substitutes can change fermentation processes in the rumen and influence methane production. Feeding corn or legume silages, starch or soya decrease methane production compared to grass silages. Combining maize and legume silage also reduces nitrogen (N) excretion in urine which can have both GHG and water quality benefits in some systems. Corn/maize and legume silages often increase feed intake and production in dairy cows as compared to grass silages.

Measure: prevention, control & eradication of diseases

Prevention of animal diseases and early treatment is key in improving animal health and productivity, reducing mortality and morbidity, and preventing further outbreaks. Improving farm biosecurity measures are important to protect the farm from incoming diseases as well as to help prevent outbreaks of diseases to other farms. Improved animal health status will improve animal productivity. Nevertheless, cost-

[138] National Inventory Report (NIR), CHMI, 2017
[139] https://unfccc.int/sites/default/files/resource/17589243_Czech%20Republic-NC7-BR3-1-NC7_BR3_CZE.pdf

effectiveness of measures depends on baseline incidence of disease, options for disease control and their costs, and expected net benefits.[140]

Measure: manure management and storing

Collection and storage facility in housing system with concrete floors or other hard material (hard clay), with the use of simple equipment which prevents the run-off of valuable nutrients into environment, as well as allow to keep the hygiene of lactating cows. Farming systems using feedlots have significant potential to improve collection of manure and urea, offering the co-benefit of being able to use these nutrients as fertilizer. It has high mitigation potential, also does not require much investment.

Measure: animal genetics and breeding - Efficient & robust animals

Breeding and reproduction organizations have increasingly focused on breeding more efficient, stronger animals. Animals are constantly able to increase their production per unit due to disease and environment and management changes. It is now available to farmers to ask breeding companies to label their produce in terms of resource efficiency, vulnerability to disease or stress, and adaptability to different climatic conditions. Genetic improvement currently represents an annual increase in efficiency of 0.5% to 1% (as this is a best practice in New Zealand, it also takes into account the increase in efficiency per capita per year).

Above mentioned practices are more cost-effective for the farmer; however, the initial costs of research and breeding programs are high and require a long investment. In addition to finding new ways, the key to success will be to encourage breeders to include mitigation of GHG emissions in their breeding programs. Options for engaging the agri-food industry are to improve the interaction between the breeding organization and the end-users and market ((including any incentives from governments), to encourage early investment in new programs, and to explore breeding opportunities, low emission intensity.[141]

[140] DISCONTOOLS, https://www.discontools.eu/

[141] "Reducing greenhouse gas emissions from livestock: Best practice and emerging options", Global Research Alliance, Link: https://saiplatform.org/uploads/Modules/Library/lrg-sai-livestock-mitigation_web2.pdf

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