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Assessment of Land Use, Land Use Change and Forestry Sector Potential in Achieving Climate Change Mitigation Objectives in Armenia

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The objective of this Policy Note is to provide recommendations in setting long-term targets of the greenhouse gas emissions/removals for the national strategies in Land Use, Land Use Change and Forestry sector, in accordance with the priorities of that sector's development in Armenia and in line with the EU practices and regulations.

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Table of contents

SUMMARY 2
INTRODUCTION 4
1 STATE OF THE LULUCF SECTOR 4
1.1 Forest lands 5
1.1.1 State of the Armenian forest 5
1.1.2 Forest trend and challenges 5
1.2 Agricultural lands 6
1.2.1 State of the Armenian Agriculture 6
1.2.2 Armenian Agriculture trend and challenges 7
2 CLIMATE CHANGE STRATEGY AND LULUCF SECTOR IN ARMENIA 7
2.1 National Strategy and Framework 7
2.2 Role of LULUCF sector 8
2.3 Current Inventory, baseline and perspective 8
2.1.1 LULUCF GHG Inventory and baseline 8
2.1.2 National objectives and perspectives 10
3 POLICY OPTIONS, MITIGATION OPPORTUNITIES AND PRIORITIES 10
3.1 MOST PROMISING POLICIES AND MEASURES 10
3.1.1 Afforestation/Reforestation 11
3.1.2 Restoration of degraded forests 12
3.1.3 Sustainable forest management 14
3.1.4 Regulating the harvesting of wood energy 15
3.1.5 Optimization of grasslands 17
3.1.6 Plantation of perennial crops 18
3.1.7 Development of agroforestry and hedgerows 20
3.2 OTHERS POSSIBLE MEASURES 21
3.3 SUMMARY OF LULUCF MITIGATION OPPORTUNITIES 22
3.4 MARGINAL MITIGATION COST CURVE 24
3.5 ADDITIONAL RECOMMENDATIONS 25
3.5.1 National Land Monitoring System 25
3.5.2 Appropriate Sustainable Financing Framework 26
CONCLUSION 27
REFERENCES 28

SUMMARY

The latest National Communication of Armenia (Republic of Armenia, Ministry of Environment, 2020b) indicates that emissions without LULUCF (Land Use, Land Use Change and Forestry) reach 10,283.9 ktCO_2eqv in 2016. Energy and Agriculture represent the main emitting sectors with respectively 64% and 22% of emissions. The LULUCF sector presents a sink of 483 ktCO_2eqv in 2016 which corresponds to 5% of GHG emissions of Armenia.

Land Use, Land Use Change and Forestry (LULUCF) sector is a key intervention element in climate change mitigation policies. Globally as well as for Armenia, the achievement of climate targets implies the enhancement of carbon sinks and the prevention of carbon release on lands.

In this study, very large investigations were led on possible mitigation actions on lands. For each possible mitigation action, estimation of GHG benefit was estimated by making assumptions on:

- The **possible magnitude of actions in Armenia** (for instance 10,000 ha/year afforested for 25 years between 2020 and 2045). These assumptions were based on existing national documents (for instance the NDC of Armenia in the case of expected afforestation), or on specific analysis based on history and land use distribution. The assumptions were presented to local Armenian experts before validation.
- The **unitary effect of actions in Armenia** (for instance 174 tCO_2eqv/ha afforested). These values chosen after considering international and national literature on carbon stocks, carbon dynamics for similar ecological zones. It may include CO_2 emissions and removals for living biomass, dead biomass and soil. It also considers GHG emissions other than CO2 in relation with biomass burning. All estimates of emissions/removals presented in this report are done by CITEPA/ONFi.

This study analyzed nearly 30 possibilities of mitigation actions but only a few of them present clear messages for Armenia situation:

- Afforestation/Reforestation;
- Restoration of degraded forests;
- Sustainable forest management;
- Regulating the harvesting of wood energy;
- Optimization of grasslands management;
- Plantation of perennial crops;
- Development of agroforestry and hedgerows.

In this study, it appears that afforestation is by far the most capable action to reduce greenhouse gas emissions in Armenia. Restoration actions can also show large benefits in forests and grasslands when ambitious assumptions are considered:

- The afforestation of 250,000 ha would generate an additional sink of 44 MtCO_2eqv for the entire period 2020-2050.

- The restoration of 200,000 ha of forest would generate a reduction of emissions around 7 MtCO_2eqv for the entire period 2020-2050.

With all studied actions, a cumulated sink of 62 MtCO_2eqv is obtained over the period 2020-2050 with an annual maximum sink reached around 3,000 ktCO_2eqv/year.

For main actions, costs were estimated. The costs are comprised between $10 and $80 per ton of CO_2eqv for most mitigation actions. It appears that forestry mitigation activities are cost-effective compared to agricultural activities. Some forestry activities are less costly to implement (e.g., avoided deforestation) and the forest sector offer significant potential for emissions reductions resulting from higher carbon stocks. Actions on forest areas may also be easier to conduct because a large part of the forest is not owned by private owners and public policies may be easier to decide for these areas, compared to agricultural areas where there are mostly private owners.

This project confirms that the LULUCF sector is a cost-effective mitigation opportunity and a competitive solution compared to other industrial sectors such as transportation or construction.

For this analysis, attention was paid to the consistency of actions on the territory. It considers especially the availability of lands for afforestation or for perennial crop plantation. It also considers the wood fuel supply as a critical constraint on actions.

It is also reminded that the monitoring is essential to accompany mitigation actions and it is recommended that at least two additional national frameworks be put in place that are currently lacking:

- A renewed national land monitoring system. There are many ways to collect information, available data based on ground observations, and very accurate tools for land use and land cover mapping. The last forest inventory is outdated (1993). This limits the knowledge of the actual state of forests in Armenia. To take appropriate measures regarding forests, it is strongly recommended to conduct new forest inventories.
- A sustainable and incentive-based financing framework. The actions listed in this study are ambitious and to ensure the feasibility of implementation and sustainability of mitigation activities, it is strongly recommended to put in place an appropriate legislative and institutional framework providing adequate financial status and sufficient incentives to achieve the objectives.

INTRODUCTION

The Armenian government is currently supported by the EU4Climate project to act against climate change. This support, funded by the European Union, is implemented by the United Nations Development Program (UNDP). The objective of the main program is to support countries, including the Republic of Armenia, in improving climate policies and legislation that contribute to their low-emission and climate-resilient development and to achieving their commitments to the Paris Agreement on Climate Change.

With respect to agriculture, forestry and other land use sectors, the Paris Agreement states that the contribution of land use and forests to achieving long-term climate mitigation goals will be critical in achieving carbon neutrality.

In this context, this paper puts into perspective the role of LULUCF sectors in GHG emissions and the prospects for the sector's contribution to the country's mitigation policy in a long-term low-emission development objective. This overview leads to recommendations for setting long-term GHG emission/removal targets in line with the development priorities of this sector in Armenia, before providing policy and economic guidance for achieving them.

1 STATE OF THE LULUCF SECTOR

The latest National Communication of Armenia (Republic of Armenia, Ministry of Environment, 2020b) presents GHG emissions for the time series 1990-2016. GHG emissions are slightly increasing since 2000, although they were much higher in 1990. According to this inventory LULUCF represents a slightly decreasing sink for the period 1990-2016.

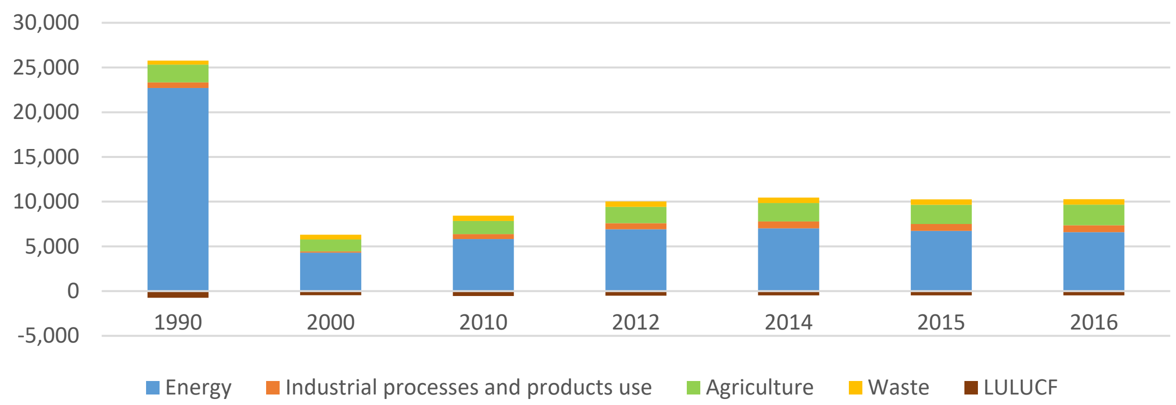

Figure 1 : GHG emissions with breakdown by sectors (kt CO_2eqv), 1990-2016

Table 1 : GHG emissions with breakdown by sectors (kt CO_2eqv), 1990-2016

kt CO_2eqv	1990	2000	2010	2012	2014	2015	2016
Energy	22 712	4 299	5 830	6 917	7 014	6 731	6 595
Industrial processes and products use	630	143	555	676	783	767	772
Agriculture	1 989	1 327	1 462	1 827	2 045	2 148	2 296
Waste	439	533	583	599	611	616	622
LULUCF	-736	-454	-541	-513	-477	-474	-483
Net GHG emissions	**25 035**	**5 847**	**7 889**	**9 506**	**9 975**	**9 787**	**9 801**

Land in Armenia is mainly covered by grassland, which accounts for almost 48% of the territory, followed by cropland (20%) and forests (11.2%) (FAO, 2020). Urban areas, wetlands, and other lands are relatively marginal and have mostly not undergone significant changes in recent decades.

Since 1987, the main trends in land use distribution and change dynamics in the country have been a decrease in cultivated areas, a marginal increase in forested areas, and relative stability in grassland areas.

Therefore, in Armenia, the main LULUCF activities that can significantly contribute to GHG mitigation policy are grasslands and agriculture and forestry. Before analyzing the mitigation potential and opportunities, we will briefly describe the situation of each of these sectors and their respective issues in the current Armenian context.

1.1 Forest lands

1.1.1 State of the Armenian forest

In 2020, forests cover 11.2% of Armenia's territory, or more than 328,000 hectares (FAO, 2020), including 18,000 hectares of planted forests, characterized by significant geographical disparities where preserved forest lands are mainly in the northeast (62%) and southeast (36%) of the country.

Armenia's forests have been severely degraded due to the political and socio-economic situation in the country, especially in 1990s. Armenia has seen more than half of its natural forests shrink over the past few centuries, mainly due to anthropogenic factors but also to continuous aridification (Sayadyan, 2006).

Today, easily accessible forest areas have almost disappeared, and rich tree species have become scarce. The remaining forest areas are less accessible for forestry activities (topography, long distance to urban areas, lack of exploration roads) or with low level of biomass that makes the forest harvest weakly interesting. . This leads to a "mechanical" reduction of forest disturbances related to anthropogenic factors. The main risks for the remaining forests now seem to be related to natural disturbances (fires, diseases, etc.), which are increasing due to the effects of climate change.

In addition, forest regeneration is very limited in Armenia, mainly due to pressure for firewood harvesting and overgrazing.

Due to their depletion, Armenia's forests currently play a limited role in climate change mitigation and, on the other hand, cannot support a sustainable forest economy, even though wood products and especially fuelwood are an important issue for the country.

1.1.2 Forest trend and challenges

1.1.2.1 Highly degraded forest

The main uses of the forest in Armenia are for fuelwood consumption by rural households as well as for charcoal demand by Armenian restaurants, most of which use the traditional method of cooking over wood fires. One reason for this high demand is the high price of alternative fuels, especially gas. Pasoyan & Sakanyan (2019) consider that the demand for fuelwood significantly exceeds (at least 20 times) the supply of fuelwood, persistently leaving damaging impacts on forests, with harvesting exceeding the natural recovery rate.

At the same time, grazing is not clearly regulated in Armenia, forests adjacent to local communities are damaged by overgrazing of livestock, large and small, due to lack of fodder and inaccessibility of pastures and hayfields. In particular, the use of the forest as shelter and fodder for grazing livestock damages natural regrowth and seedlings (Khechoyan, 2018). Therefore, grazing of large and small livestock in forests also contributes to forest degradation. By destroying natural regrowth, the forest is deprived of young trees and if grazing is continuous, degradation occurs.

The annual deforestation rate in Armenia is relatively low, in part due to the scarcity of forests. In recent decades, data show that about 450 hectares have been deforested each year. The deforested area is low and correspond to areas seen as converted to croplands, grasslands or settlements. Most of the deforested land are land converted to cropland and grassland indicated by remote sensing technologies. The areas are estimated by comparing initial and final land covers for a given period. At the same time, it is crucial to specify that there is no real need for extension of agricultural areas in Armenia. Consequently deforestation, defined as a conversion to another land use is not the major issue. The main concern is forest degradation. It differs from deforestation because degradation will not obviously lead to a land use change (these degraded lands are reported as forest remaining forest in GHG inventories). Yet although conversion to agricultural land is not an objective as such, large degradation may lead to the conversion into grassland insofar as these areas may offer grazing areas for livestock. Conversion to grassland is thus more a consequence than an objective.

Finally, forest fires, primarily caused by human negligence but exacerbated by climate change conditions, also contribute significantly to forest degradation. However, it should be noted that in recent years, preventive measures taken in Armenia, have limited the damage caused by human-induced forest fires on forests (Khechoyan 2018).

Ultimately, the combined effect of uncontrolled access to forest leading to overexploitation, and the depletion of open forest areas could lead to economic and social tensions, especially in terms of access to energy for rural populations.

1.1.2.2 Low increase in forest cover

Industrial and commercial logging is prohibited in Armenia, and the government does not issue licenses for commercial logging. Moreover, the current composition and configuration of forest resources in Armenia limits the potential for commercial logging anyway. Indeed, the natural forests are too disparate and the most valuable tree species are now too rare to stimulate private investment in the sector. The only harvests allowed are for sanitary felling to prevent the spread of pests and diseases, or regular thinning to maintain protected forests while climate change creates favorable conditions for their massive spread in Armenia (Hertel et al., 2004).

This lack of private actors in the logging sector also logically prevents any investment in forest plantations for productive purposes. As a result, experiences with forest plantations are very limited in Armenia, and are only carried out for restoration/conservation purposes by the government or civil society.

1.2 Agricultural lands

1.2.1 State of the Armenian Agriculture

Agriculture is one of the key sectors of the Armenian economy, contributing about 15-16% of GDP in recent years. The main types of agricultural production in Armenia include grains and potatoes, vegetables, market gardening, grapes, fruits and berries, meat, milk, eggs (Republic of Armenia, 2020). However, livestock production remains the main driver of the sector. In 2020, 53% of Armenia's gross agricultural product was attributable to livestock.

The total area of agricultural land in Armenia covers over 2 million hectares. With 1.2 million hectares, pastures and meadows are the main use, ahead of arable land - 446.0 thousand hectares (21.8%) and perennial plantations - 34.8 thousand hectares (1.7%). These areas are supplemented by other agricultural land in the amount of 391.2 thousand hectares (19.2%) (Republic of Armenia, 2020).

1.2.2 Armenian Agriculture trend and challenges

1.2.2.1 Land degradation and abandonment

One of the main problems in the sector is land degradation and abandonment. It is estimated that one third of agricultural land in Armenia is unused and abandoned, while more than half of the pastures and grasslands are now degraded, mainly due to overgrazing (UNCCD, 2018, GEF-WB, 2014).

The main drivers of land degradation are water stress, soil erosion, and the desertification process. It is estimated that about 81% of the Armenian territory is exposed to desertification due to natural and anthropogenic factors, such as inefficient agricultural practices, illegal logging, overexploitation of groundwater resources (artesian wells), mining, soil contamination.... Currently, a decrease in soil fertility, reduction of carbon stocks and activation of erosion processes are observed in all natural areas of Armenia (UNCCD, 2018; GEF-WB, 2014). All this plays unfavorably on the productivity and competitiveness of Armenia's agricultural sector.

It should also be noted that livestock farming has led to overgrazing of subalpine and alpine meadows, areas with significant biodiversity and landscape values that are now under threat.

2 CLIMATE CHANGE STRATEGY AND LULUCF SECTOR IN ARMENIA

2.1 National Strategy and Framework

The Republic of Armenia ratified the United Nations Framework Convention on Climate Change (UNFCCC) in May 1993 and the Kyoto Protocol in 2002 as a developing country included in the non-Annex I category of the Convention.

More recently, the Republic of Armenia ratified the Paris Agreement and the Doha Amendment to the Kyoto Protocol in 2017.

Armenia's position under the Paris Agreement is outlined in its "Nationally Determined Contribution 2021-2030" (Republic of Armenia, Government, 2021), setting the ambition of the Government of Armenia towards reduction of greenhouse gas (GHG) emissions by 40% compared with base year 1990 by 2030.

In 2020, the Republic of Armenia submitted its "Fourth National Communication" (NC4) covering the greenhouse gas (GHG) inventory for the period 1990-2016 (Republic of Armenia, 2020).

The Armenian government is currently supported by the EU4Climate project to act against climate change. The project supports Armenia's commitment to update and improve the country's NDC, with the aim of defining the Long-Term Low Emission Development Strategy (LT-LEDS-) for successful implementation of Armenia's consecutive NDCs, as well as the achievement of the sustainable development goals, through a cross-sectoral approach including forests and agriculture.

2.2 Role of LULUCF sector

Because terrestrial ecosystems continuously exchange carbon fluxes with the atmosphere, the terrestrial sector plays a key role in the carbon cycle as a source and sink of emissions.

On the one hand, terrestrial ecosystems sequester carbon through natural processes related primarily to biomass growth. On the other hand, anthropogenic activities related to agriculture, forestry and other land uses contribute to the release of some of this carbon, which also has natural causes.

The LULUCF sector is therefore a key intervention element in climate change mitigation policies. The main objective is for the sector to be a net sink of emissions, by increasing carbon storage capacities on the one hand and decreasing emission sources on the other.

In the LULUCF context of Armenia described above, two major groups of activities can play an important role in Armenia's GHG balance and are therefore strategic directions in the country's mitigation policy:

- **Forest land:** Forests impact net greenhouse gas (GHG) budgets in two ways. First, they remove carbon dioxide (CO2) from the atmosphere and sequester carbon in biomass, thus acting as a gross carbon sink. Second, some of this carbon is transferred to the soil through litter, mortality and crop residues, or through harvesting as various products. Depending on the balance between CO2 entering the system and CO2 leaving, a net long-term balance occurs. Therefore, forest management tools such as improved forest management, afforestation, reforestation, restoration, and reduced deforestation can help increase the net carbon sequestration in forests. In addition, the carbon footprint also depends on the life span of wood products. Long-lived wood products (e.g., lumber) delay the release of carbon to the atmosphere and contribute favorably to the GHG balance, while short-lived wood products, such as firewood consumption, tend to accelerate the release of carbon to the atmosphere.
- Croplands and grasslands act as both a sink and a source of emissions. The storage effect is generally provided by biomass and organic soil, while the emission sources generated depend on agricultural practices such as enteric fermentation, fertilizers, manure, fires, energy uses, etc. Therefore, there are a range of options for mitigating GHG emissions from agriculture, such as improved crop and pasture management (e.g., improved agronomic practices, nutrient use, tillage, and land management. residues), restoration of organic soils and degraded lands, conversion to agroforestry crops, and improved livestock and manure management.

In addition, land-based mitigation options are commonly accepted among the most cost-effective options for sequestering carbon emissions. Moreover, these mitigation options are associated with numerous economic and environmental co-benefits that argue for prioritizing implementation of land-based solutions.

2.3 Current Inventory, baseline and perspective

2.1.1 LULUCF GHG Inventory and baseline

According to the latest GHG inventory report (Republic of Armenia, 2020a), the country's total CO_2eqv emissions (excluding the LULUCF sector) amounted to 10,624 kt CO_2eqv in 2017, while the LULUCF sector represented a net sink of -444 kt CO_2eqv in 2017. Thus, the LULUCF sector officially offset 4% of the emissions from the other sectors in 2017.

Table 2 : LULUCF official reporting (kt CO_2eqv)

kt CO_2eqv	2010	2011	2012	2013	2014	2015	2016	2017
Forest	-553	-551	-527	-536	-540	-539	-547	-530
Cropland	1	15	10	-5	-7	-7	-7	-7
Grassland	0	1	-2	25	18	18	18	18
Wetlands	2	2	2	6	6	8	8	19
Settlement	0	1	6	7	1	0	0	0
Other land	25	24	0	53	69	65	65	55
Biomass burning (Forest+crop+grass)	7	6	6	6	6	7	6	10
Total	**-525**	**-508**	**-510**	**-450**	**-451**	**-454**	**-463**	**-446**

However, in the context of this study, some elements of the inventory were refined using satellite imagery data and some emission calculations were corrected according to IPCC guidelines. The objective of these corrective measures is to establish a refined baseline in order to accurately identify the mitigation potential of the sector by 2050.

Table 3 : LULUCF revised estimates for this study (kt CO_2eqv)

kt CO_2eqv	2010	2011	2012	2013	2014	2015	2016	2017
Forest (including forest fires)	84	69	58	51	49	49	44	72
Cropland (including cropland burning)	129	126	122	119	116	112	112	112
Grassland (including grassland burning)	55	50	44	39	34	29	27	25
Wetlands	32	30	29	24	23	24	24	35
Settlement	3	3	3	3	2	2	2	1
Other land	4	4	3	2	2	1	1	1
Total	**307**	**281**	**260**	**239**	**226**	**217**	**210**	**246**

The main difference between the two sources appears in the GHG balance of forests and croplands, where their balance seems to be overestimated in the official inventory. This seems to be mainly due to the absence of satellite imagery monitoring. The national inventory establishes the net balance of the evolution of the surface areas of each sector from accounting data which generally tend to mask the complex dynamics of land use changes.

By using specific assumptions on wood harvest and new land-use data, the profile of the LULUCF sector changed a lot and turned from a net sink to a net source. This result may alert some stakeholders insofar as this assessment indicate a degradation of the carbon stocks and possibly a degradation of producing lands. This is not surprising as far as harvest activities are known to represent a big pressure in Armenia. Yet it remains relevant to be cautious with figures, and a few assumptions may dramatically change the emissions and the removals of the country. It confirms, if necessary, that data collection is essential and that it is useful to crosscheck a lot of data sources (field measurements, surveys, remote monitoring) to strengthen the reliability of estimates.

Regardless of the sector, emission trends have been relatively stable over the last decades, which makes it possible to forecast an equivalent baseline in terms of GHGs for the next periods until 2050.

2.1.2 National objectives and perspectives

In the context of the global goal of climate neutrality, reducing emissions but also increasing the sink capacity of the LULUCF sector is of critical importance. As stated in the Paris Agreement, the contribution of these sectors is essential to achieving long-term climate mitigation and adaptation goals, including carbon neutrality.

Achieving carbon neutrality will require reductions in emissions from the most polluting sectors and a significant increase in LULUCF's emission removal capacity. For the moment, the gap is important, between 10 624 kt CO_2eqv (excluding the LULUCF sector) and a LULUCF sector emission removal below 400 kt CO_2eqv whatever the source. Ambitious improvements must be made in the LULUCF sector.

As of now, Armenia's key commitments in the LULUCF sector are highlighted in its first NDC (Republic of Armenia, Government, 2015b). The LULUCF sector is then included in the overall mitigation target, with the goal of reaching 20.1% forest cover by 2050 but also with the goal of ensuring conservation, accumulation and storage of organic carbon in all land categories. The NDC 2021-2030 refers to the draft National Forestry Programme according to which it is planned to increase of forest cover to 12.9 per cent of the territory of Armenia by 2030.

However, these ambitions are not accompanied by GHG estimates. Thus, the remainder of the note focuses on highlighting the main actions that can be considered within the LULUCF sector in Armenia and providing initial estimates of the potential of these actions. This will eventually put the potential of the LULUCF sector in perspective with the necessary efforts, and thus help the authorities to set concrete targets for the LULUCF sector.

3 POLICY OPTIONS, MITIGATION OPPORTUNITIES AND PRIORITIES

3.1 MOST PROMISING POLICIES AND MEASURES

Mitigation measures are highly dependent on specific country situations, but most are well known and appropriate in many countries. According to the IPCC Special Report on Climate Change and Land, key mitigation actions in the LULUCF sector are related to sustainable food production, improved and sustainable forest management, soil organic carbon management, ecosystem conservation and land restoration, reduced deforestation and degradation, and reduced food loss and waste (IPCC, 2019).

Based on a large-scale analysis of potential mitigation actions in the LULUCF sector, in line with good practice and IPCC recommendations, this section describes the most promising of these for Armenia based on the mitigation potential as well as the cost-effectiveness of each. A list of expected co-benefits for each measure is also described.

The most promising measures selected and detailed in the following sections are:

- Afforestation/Reforestation;
- Restoration of degraded forests;
- Sustainable forest management;
- Regulating the harvesting of wood energy;
- Optimization of grasslands management;
- Plantation of perennial crops;
- Development of agroforestry and hedgerows.

3.1.1 Afforestation/Reforestation

3.1.1.1 Rationale

Afforestation and reforestation actions are based on planting but can also be based on natural or assisted regeneration, especially on land abandoned by agriculture and on old forests. Tree growth will naturally generate higher carbon storage in living biomass than storage on previously used land such as cropland or grassland. Therefore, these actions will increase the carbon sink potential of the LULUCF sector.

3.1.1.2 National circumstances

RA has experienced afforestation/reforestation activities before, but mainly between the 1950s and 1980s when 90,000 ha of pine trees were planted. Since then, afforestation or reforestation areas have been limited to a few hundred hectares per year (about 200 ha/year), including the natural dynamics of conversion of grasslands to forests due to abandonment of agriculture.

Very ambitious target has recently been set to extend forest cover to 20.1% of Armenia's territory by 2050. This commitment, enshrined in the Nationally Determined Contribution to the Paris Agreement, could offer the greatest mitigation potential for the LULUCF sector, but will of course face major challenges, especially considering the fragmentation of private lands that would require an unprecedented coordination effort. For comparison, several periods of reforestation and afforestation measures between 1998 and 2018 expanded the forest by about 8,000 hectares, while the 20.1% target for 2050 would correspond to a reforestation effort equivalent to 250,000 ha. It was also noted that Armenia is part of the "Bonn challenge"[1] which aims at restoring degraded areas with tree plantations. In this framework Armenia indicates a pledge of 50,000 hectares planted for 2030 but it remains difficult to assess how ambitious such afforestation rates are. Different ways may help to contribute to this plan. By supporting afforestation (for instance tax breaks related to afforestation activities) and considering that there is low pressure on lands for agricultural purposes it is possible to imagine large afforestation dynamics.

3.1.1.3 Potential target

Taking the ambitious target as the main target, it would be necessary to afforest or reforest nearly 250,000 ha, which seems very difficult to achieve. During the study it was proposed to reduce this objective in this simulation but, considering the feedbacks of stakeholders, this objective was kept unchanged.

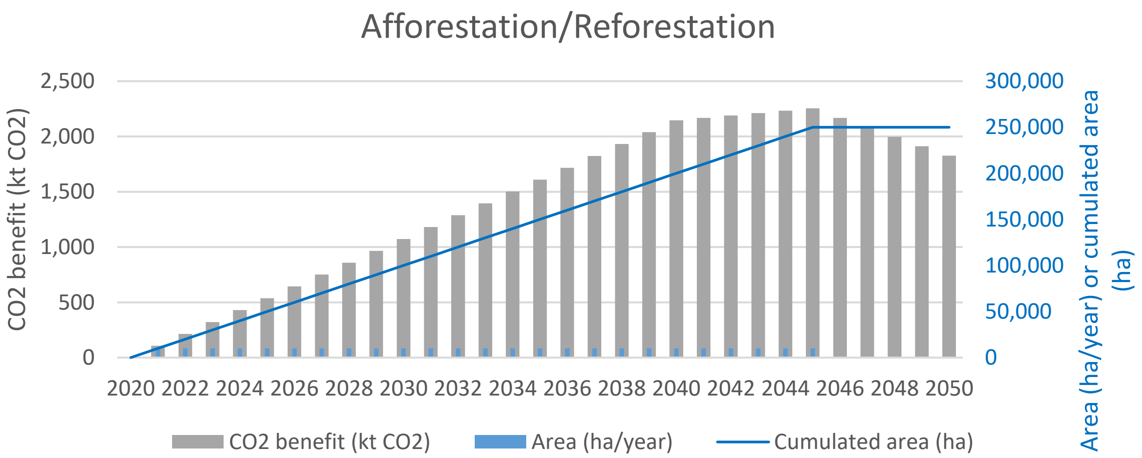

Figure 2 : CO_2 benefit, area per year and cumulated area for afforestation/reforestation

[1] The Bonn Challenge is a global effort to bring 150 million hectares of degraded and deforested land into restoration by 2020 and 350 million by 2030 (https://www.iucn.org/theme/forests/our-work/forest-landscape-restoration/bonn-challenge).

Based on the IPCC recommendations, the estimated average impact of the action in Armenia on 1 ha could result in a reduction of 215 tCO_2eqv over 20 years, i.e. 10.73 tCO_2eqv per hectare per year for the first 20 years and 2.16 tCO_2eqv per ha per year thereafter. As a result, the overall impact of this mitigation action is estimated at 43,579 $ktCO_2eqv$ for the entire 2018-2050 period[2].

3.1.1.4 Cost-effectiveness

The costs of implementing afforestation measures depend on many parameters and are complex to assess without a clear afforestation program plan. For example, based on a review of the literature and estimated costs from several experiments around the world, the range for planting and maintaining trees is $1000-$3000/ha (Dittrich, 2019, UNCCD, 2018, McKinsey, 2013, FAO, 2010, IPCC, 2004, Kolshus, 2001, GCF, 2020). Compared to the mitigation potential per ha of the action, the average cost-benefit of the action is estimated to be $6-$17/tCO_2eqv.

3.1.1.5 Main Co-benefits

Beyond the climate impacts, the main co-benefits of this measure come from

- Enrichment of biodiversity through increased intact and connected forests;
- Improved soil health through improved soil infiltration by vegetation and soil fauna under the forest;
- Improving water supply and quality by helping to regulate stream and river flows and improving nutrients in watersheds.
- Increased supply of non-timber forest products (NTFPs) for local communities.

3.1.2 Restoration of degraded forests

3.1.2.1 Rationale

Forest degradation, such as deforestation, also affects the GHG balance. In forests, logging, fuelwood extraction, fires, and grazing generally reduce carbon stocks faster than they can be naturally offset. A degraded forest has a lower capacity to remove CO2 and store carbon over the long term. Trees are more fragile, and mortality, fire, pests, and other disturbances are more likely, increasing the risk of emissions and decreasing the forest's sink capacity. Thus, restoration of degraded forest ecosystems may have significant potential for climate mitigation.

Restoration of degraded forests can take many forms, this can include physical protection of degraded areas, tillage to promote mineralization or even fertilization, forestry interventions to limit the number of shoots per stump, and of course tree planting in areas where regrowth is not naturally sufficient.

3.1.2.2 National circumstances

Armenia's forests have been severely degraded in recent history due to the country's political and socio-economic situation. Armenia has seen more than half of its natural forests reduced before, during the last centuries, mainly due to anthropogenic factors, such as firewood harvesting, overgrazing of large and small livestock in the forests but also due to continuous aridification (Sayadyan, 2006).

Loss of soil and aridification are both resulting to loss of fertility and can prevent regrowth of forest. High mortality rates are often registered on large scale actions where plantations are not enough well prepared.

[2] The effect of afforestation is not constant overtime. In the calculation the sink generated by afforestation includes a contribution of litter and soil which stops after 20 years considering that a maximum is reached after 20 years. This explains the slight decrease of the sink after 2045. The growth of trees continues after 20 years but wood harvest is considered and impacts the sink on afforested areas.

It is often not possible to plant the species that were in place before degradation, but in most cases, restoration and tree growth remain possible when tree plantations are protected and cautiously put in place.

Recognizing this situation, several national programs and projects are currently underway in Armenia with the aim of reducing land degradation and restoring degraded forests. In particular, the implementation of Armenia's Land Degradation Neutrality Commitments through Sustainable Land Management and Restoration of Degraded Landscapes project plans to restore 7,300 ha of degraded forests in the coming years.

3.1.2.3 Potential target

Given the estimated cumulative level of fuelwood harvested in recent years (7 million m3 for 10 years), the area to be restored could be estimated by considering all areas that have lost this volume of wood. With an assumption of 35 m3 harvested per ha, 200,000 ha of forest must be restored, which suggests the implementation of restoration activities on 10,000 ha each year for the next 20 years.

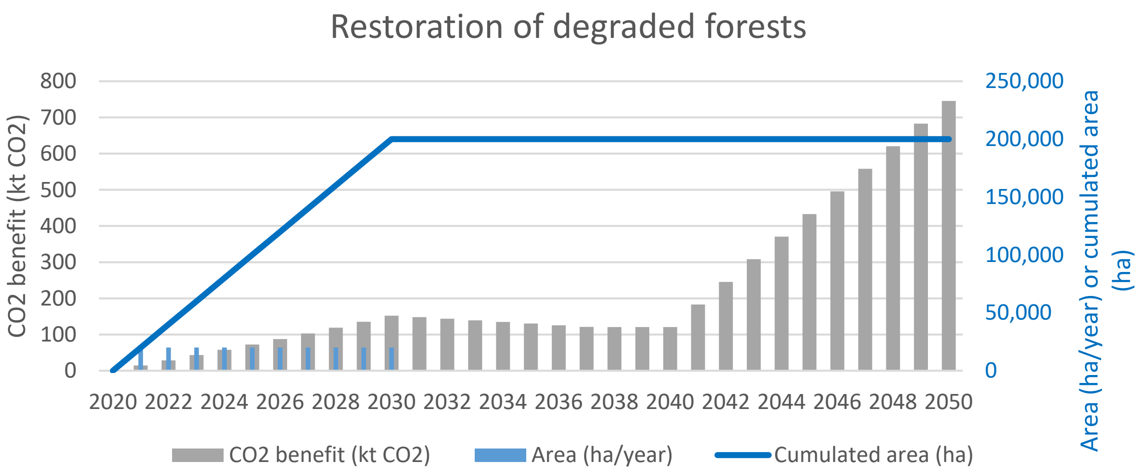

Figure 3 : CO_2 benefit, area per year and cumulated area for restoration of degraded forest

The areas concerned by this action would present a sink of 3.12 tCO_2/ha/year after 20 years due to both increasing growth and decreasing harvest on restored areas (equilibrium between growth and harvest is considered for the first 20 years). This benefit is significant considering that currently forest are net emitters. Thus, the overall mitigation impact of this action could reduce emissions by 6,791 $ktCO_2eqv$[3].

3.1.2.4 Cost-effectiveness

The cost of implementing this mitigation activity varies widely depending on the level of degradation of the targeted forest and, therefore, the type of activities that will be implemented. This can range from simple protection for natural regeneration, to active restoration including planting activities. For this, the average cost of this activity is set at three times less than the cost involved for an afforestation activity with a lower planting density (Dittrich, 2019, McKinsey, 2013, UNCCD, 2018, FAO, 2010, IPCC, 2004, Kolshus, 2001, GCF, 2020). The approximate cost range is therefore set from \$250 to \$1000/ha. Considering 34tCO2eq / ha as the marginal mitigation impact, the cost-effectiveness of the measure is set at \$7 to \$229 / tCO_2eqv.

3.1.2.5 Main co-benefits

Beyond the climate impacts, the main co-benefits of this measure come from:

[3] The effect of restoration is not constant overtime. In the calculations, restoration impacts living biomass. Restoration process implies some wood harvest for the first 20 years and don't lead to additional sink very quickly. High growth rates are reached after 20 years thanks to restoration activities.

- Enrichment of biodiversity through the rehabilitation of intact and connected forests;
- Increased soil health by improving infiltration by vegetation and soil fauna under the forest;
- Increased water supply and water quality by supporting stream and river flow regulation and improving watershed nutrients.

3.1.3 Sustainable forest management

3.1.3.1 Rationale

Sustainable forest management improves carbon uptake, both because the rate of carbon uptake slows as forests age due to declining net primary productivity and increasing natural mortality in old-growth forests, and also because unmanaged forests increase the risk of massive carbon losses from disturbances such as fire, insects, or disease. Therefore, harvesting mature trees and replanting or assisting natural regeneration should increase the rate of carbon uptake, while generating wood for wood products.

Key mitigation activities may therefore include planting trees in harvested areas, choice of harvesting level, frequency of harvesting, species selection, soil preparation, but also conversion of coppice to high forest or even coppice if the objective is to produce a large amount of biomass.

3.1.3.2 National circumstances

In the Armenian context, much of the current forestry policy is devoted to coppicing to provide biomass for energy, but also to sanitary felling to prevent the spread of pests and diseases, or regular thinning to maintain protected forests. Therefore, intensification of these forestry practices could increase biomass in existing forests and thus provide mitigation potential if the extent of managed forests is increased.

3.1.3.3 Potential target

Sustainable forest management could increase forest growth from the baseline for the period to 2050. With an average growth of 1.5 t d.m/ha/year for the first 20 years and 2 t d.m/ha/year for the following years. The areas concerned by this action would present a sink of 17 tCO_2 over 20 years (0.84 tCO_2/ha/year for 20 years, 1.92 tCO_2/ha/year after 20 years). This benefit is significant considering that, currently, forests are net emitters.

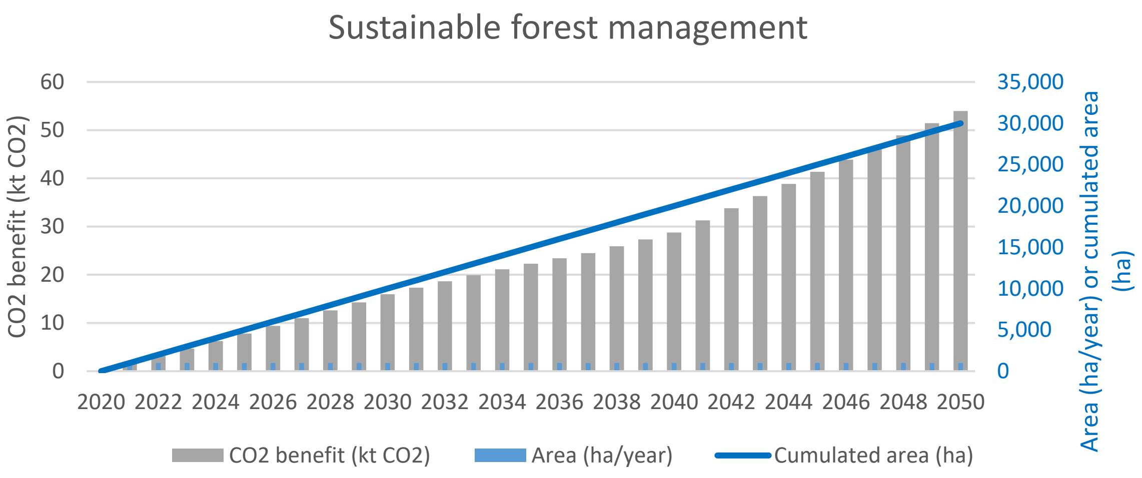

Figure 4 : CO_2 benefit, area per year and cumulated area for sustainable forest management

Considering that this action could be deployed on 1,000 ha per year for 30 years, the scale of this action could be increased to 30,000 ha of additional managed forests until 2050. The overall impact of this action will reduce emissions by 742 ktCO_2eqv for the entire 2018-2050 period[4].

3.1.3.4 Cost-effectiveness

The cost of sustainable forest management generally covers a wide range of possible activities and depends on several factors. While the main activity in the national context might be coppice management, the cost used here is approximated by the costs of regeneration activity in degraded forests and, therefore, could vary in the range of $250 to $1000 per ha (Dittrich, 2019, McKinsey, 2013, UNCCD, 2018, FAO, 2010, IPCC, 2004, Kolshus, 2001). Relative to the mitigation potential per ha, the average cost-benefit of the measure is estimated to be between $10 and $40/t$CO_2$eqv.

3.1.3.5 Mains Co-benefits

Beyond the climate impacts, the main co-benefits of this measure are:

- Reduced natural hazards and impacts from fire, pests, and diseases;
- Improving energy supply by providing biomass energy from coppicing activities;
- Promotion of local amenities in managed forests

3.1.4 Regulating the harvesting of wood energy

3.1.4.1 Rationale

Since woody biomass is considered a renewable energy source, it can be seen as a carbon-neutral energy source. However, it is not necessarily carbon-neutral, especially with respect to the combustion effect, and it is commonly accepted that it produces more carbon dioxide per unit of energy than, for example, fossil fuels. Therefore, the only way to perceive the use of woody biomass as a carbon-neutral process is to consider that over time, the growth of forests after harvesting absorbs the carbon dioxide emitted during combustion, which corresponds to a period of carbon recovery.

Therefore, regulation of wood energy harvesting must ensure that the regulated level of harvesting is compatible with forest biomass growth. In addition, this regulation must be supported by a policy of promoting alternative energy sources and improving current wood energy consumption through the use of improved stoves, for example, in order to structurally reduce wood demand. Alternatives to wood consumption must be low emission strategies, it can be based on gas consumption but preferably on renewable no carbon energies (wind, solar).

3.1.4.2 National situation

In Armenia, fuelwood is an important source of energy. These traditional uses of wood for energy are important in helping to ensure access to energy for rural families and communities, as well as demand for charcoal consumption by Armenian restaurants, but they also have negative impacts in terms of emissions, particularly because harvesting occurs in forests in an unsustainable manner. While some of the fuelwood in Armenia comes from annual allowable cuts (AACs), sanitary logging, and imported wood, the majority of the supply comes from illegal harvesting traded on the informal market.

The forest areas affected by unsustainable fuelwood harvests are not known and the total amount of annual consumption is highly uncertain, ranging from 80,000 m3 to over 1M m3 depending on the source (Pasoyan,

[4] Sustainable forest management and restoration are treated separately even if restoration could be considered as a sustainable management. In that case, the area concerned is limited to 30,000 ha because it just covers areas which are not too degraded and so no included in restoration activities.

2019, World Bank, 2020, FAO, UNECE, 2019, Perge, 2020, Junge 2011). It seems necessary to improve knowledge and monitoring of the sector before setting specific targets.

3.1.4.3 Potential target

Regulations on fuelwood or alternative energy fuels should lead to a decrease of fuelwood consumption. This decrease is necessary to allow the implementation of forestry measures like restoration. With a constant pressure on forest, forestry actions are much limited. Consequently, it is considered that the impact of this action is partially covered by actions where a decrease of wood harvest is required, in particular restoration actions.

It is supposed that this action may lead to a decrease of fuelwood from forest from 700 000 m3/year to a value around 600 000 m3/year. This decrease is beneficial for restoration of forest but may also lead to a lower harvesting pressure on all forests, in particular when new afforested areas will begin to provide wood.

This action could impact 10 000 ha per year for 10 years for a cumulative surface area of 100 000 ha. This impact would only be effective after 2040, when new afforested areas will begin to provide wood in replacement to ensure a reasonable provision of fuelwood on the period 2020-2050.

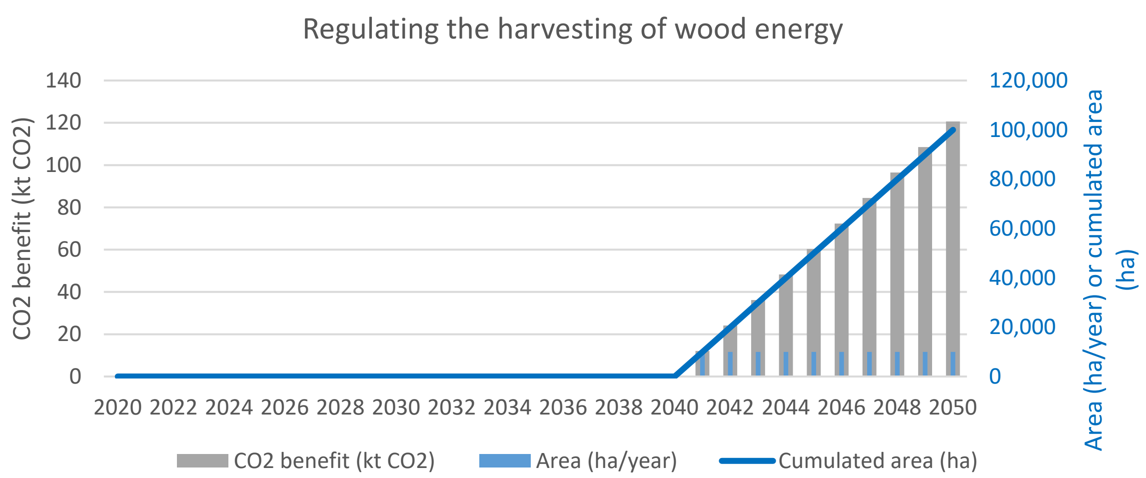

Figure 5 : CO_2 benefit, area per year and cumulated area for regulating the harvesting of wood energy

1 ha concerned by this action would present a sink of 12 tCO_2 for 20 years (0.60 tCO_2 /year for 20 years). The overall impact of this action could reduce emissions by 663 $ktCO_2$eqv over the entire 2018-2050 period. But it must be reminded that regulations on fuelwood and actions of restoration are linked[5]. It is not possible to implement restoration actions without decreasing wood harvest pressure. And it not possible to regulate fuelwood if alternatives to wood are not proposed to populations. But in this work impacts of the different actions are quantified separately.

3.1.4.4 Cost-effectiveness

To limit the harvesting of firewood, it is necessary to offer alternatives to the population for energy consumption. This can be done by dedicating new areas to coppicing, or by importing wood from other countries[6], or by facilitating access to natural gas consumption or by developing renewable electricity. Thus,

[5] For this specific action, the impacts are considered from 2040, because all policies aiming at limiting pressure on forest are supposed to facilitate actions of restoration for the period 2020-2040 and consequently already considered in action of restoration. After 2040, it is assumed that other forests can profit of the limitation of fuel wood.
[6] In recent European legislation and strategies (directive on renewable energies, green deal…), fuel wood is not really promoted anymore. It is now considered that the benefit in terms of climate is not obvious and may even be contrary

the costs will depend on the choice of policy direction and cannot be estimated precisely at this stage. The reduction of emissions estimated by this action is directly linked with investments made for afforestation covered by another action. Therefore, we consider that the cost-effectiveness of this mitigation activity could be neglected (as already covered by afforestation). Nevertheless, by applying the principle of salvage cost, i.e. the cost saved by not having to replant trees that would have been cut down for fuelwood. This cost is approximated by the cost of restoring the forest (see section Restoring Degraded Forest). The cost of the measure is then between \$250 and \$1000 per ha. Considering the mitigation potential per hectare of 7 tCO_2eqv, the marginal cost is estimated to be between \$36 and \$143 /tCO_2eqv. It is reminded that these costs are already included in the costs for afforestation and should not be cumulated with the costs of afforestation actions. For this reason, these costs are not further presented in the report.

3.1.4.5 Main co-benefits

The co-benefits of this measure will depend on the activities carried out, but in addition to the co-benefits resulting from the prevention of forest degradation (avoided loss of biodiversity, soil erosion, water scarcity, etc.), this measure could improve the living conditions of rural populations by promoting sustainable access to alternative and less harmful energy sources.

3.1.5 Optimization of grasslands

3.1.5.1 Rationale

Grassland areas are at the heart of the environmental debate because of their contribution to the multifunctionality of livestock farms and their effect on reducing environmental impacts. However, their existence depends largely on livestock activities since these surfaces are most often maintained for grazing. Grasslands are most often carbon sinks. However, the importance of additional carbon storage in grasslands, and more generally of the greenhouse gas balance, depends on their type (permanent or temporary grassland) and their management (grazing and/or mowing, animal loading, level of fertilization…).

Thus, the objective of this action is to improve the management of existing grasslands to increase their carbon sequestration potential.

3.1.5.2 National circumstances

In Armenia, many smallholders have become dependent on sheep and cattle for their livelihoods after the privatization of large collective farms. These animals generally forage in an unregulated manner in grasslands, pastures, and state forests. (Moreno-Sanchez 2005). Currently, it is estimated that more than half of all grassland ecosystems used as pastures and hayfields are in various stages of degradation, caused mainly by overgrazing.

One of the country's goals is to stop overgrazing and improve grassland management on 100% of the national territory. Armenia has initiated several pilot projects to inventory grazing practices throughout the country, recalculate grazing standards, and adapt grazing regulations to different environmental conditions and degrees of pasture degradation through the development of management plans for the use of grasslands for forage conservation and grazing.

3.1.5.3 Potential Target

According to national targets, this measure could cover one third, or about 500,000 hectares, of the total grassland area over the next 25 years. Thus, an improvement in carbon storage could be achieved on 20,000 hectares per year.

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to the objective because of the reduction of carbon sinks in forests. A global strategy would certainly not encourage wood importation for energy purposes.

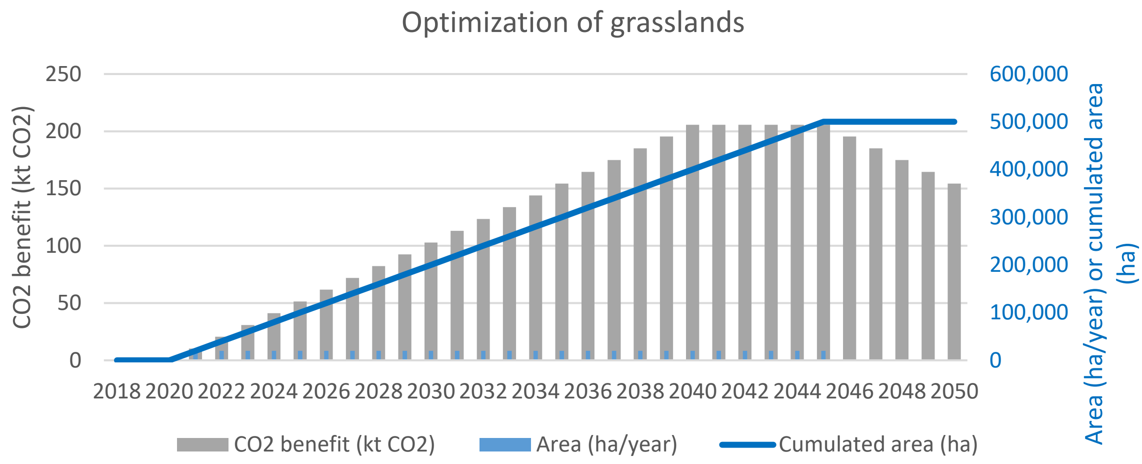

Figure 6 : CO_2 benefit, area per year and cumulated area for optimization of grasslands

The average impact of the action on 1 hectare is estimated at a reduction of 10 tCO_2 over 20 years, or 0.51 tCO_2 per hectare per year for 20 years. The overall impact of this action would therefore be to store an additional 4,063 $ktCO_2eqv$ over the entire 2018-2050 period[7].

3.1.5.4 Cost-effectiveness

The implementation of this action could mainly be achieved through capacity building and transfer of good practices to farmers for better grassland management. Under these conditions, it is often difficult to estimate a cost per hectare. Combining experiences from sustainable land management projects, studies on the cost of mitigation in the agricultural sector, and estimated costs of other mitigation activities, the average range can reasonably be set between $50 and $300 per hectare (UNCCD, 2018, McKinsey, 2013, FAO, 2012, FAO, 2010, IPCC, 2004). Considering 8 tCO_2eqv/ha as the marginal mitigation impact, the cost-effectiveness of the measure here is estimated to be $6 to $38/$tCO_2eqv$.

3.1.5.5 Main co-benefits

The main co-benefits of reducing animal densities or better management of animal rotation can be:

- An increase in soil organic matter, better infiltration and less compaction through animal management;
- Reduced risk of water contamination by limiting direct contact of animals with streams, ponds and other water sources.

3.1.6 Plantation of perennial crops

3.1.6.1 Rationale

Planting perennial crops in the form of orchards, for example, increases soil and biomass carbon sequestration and potentially reduces greenhouse gas emissions compared to cropland. Perennial crops can generate a carbon sink through carbon storage processes in the biomass. The photosynthetic effect captures atmospheric CO_2 and stores it in the woody biomass of the orchard for the life of the orchard. It is like a

[7] The effect of grassland management is not constant overtime. For this action, most of the effect is due to carbon of soil organic stock. It is considered that a maximum stock is reached after 20 years. This explains the slight decrease of the sink after 2045.

forest plantation, although carbon stocks in forests are generally much higher than those observed in orchards, because plantation densities are lower.

3.1.6.2 National situation

The planting of perennial crops is part of the main directions of the national agricultural policy that have been defined in the "RA Strategy for Sustainable Agricultural Development for 2010-2020". One of the priorities of the plant production sector is the development of horticulture through the establishment of orchards, preservation of cultivated and wild genetic resources of grapevine, preservation and sustainable use of genetic resources of agricultural crops and their wild relatives (CBD, 2019).

The area of uncultivated land has decreased through the implementation of state support programs and particularly for perennial crops through the promotion of intensive fruit and berry orchard establishment supported by affordable targeted loans. For example, the area of fruit and berry orchards increased between 2014 and 2016 by 381 hectares to 40,510 hectares in 2016. (CBD, 2019).

3.1.6.3 Potential Target

The 4th National Communication (Republic of Armenia, 2020b) highlights the sharp decline in perennial crops over the decades (from 84,000 ha in 1990 to 34,000 ha in 2017). As a result, a goal could be to reach the equivalent of 1990 perennial crops again by 2050. This will require deploying this action on about 2,000 ha per year for 25 years for a cumulative area of 50,000 hectares.

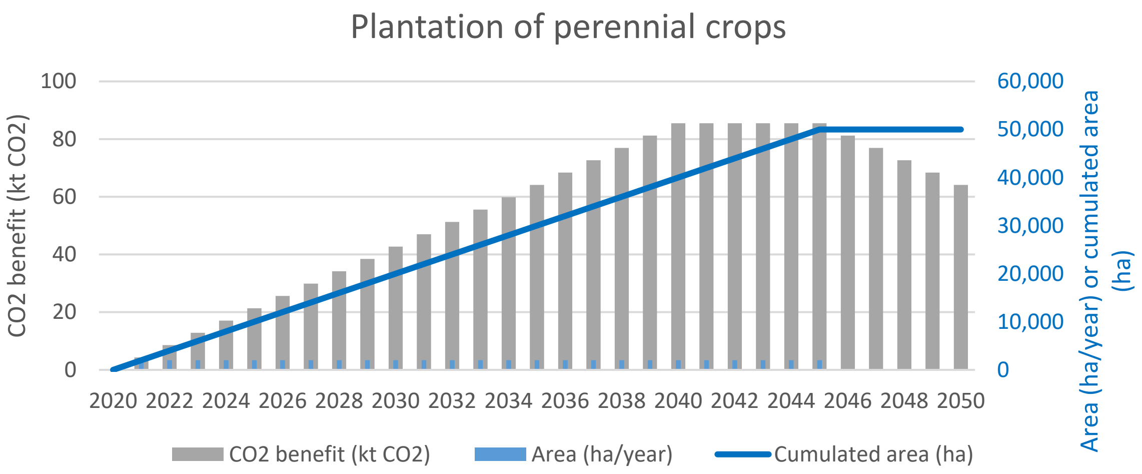

Figure 7 : CO_2 benefit, area per year and cumulated area for plantation of perennial crops

The estimated average mitigation impact of the action carried out on 1 hectare is 43 tCO_2 over 20 years, i.e. 2.14 tCO_2 per hectare per year over 20 years, which represents a total of 1,700 $ktCO_2eqv$[8].

3.1.6.4 Cost-effectiveness

The costs of converting cropland to perennial crop plantations vary greatly depending on several factors, including the type of initial crop and the type of perennial crop targeted. Since the establishment of perennial crops generates income like any other activity on cropland, the cost of the measure must take into account only the investment required for agricultural conversion. Crossing different literatures and project experiences, the average cost range can be set between $1000 and $3000/ha (UNCCD, 2018, McKinsey, 2013, Harutyunyan, 2012, Thuy, 2019, FAO, 2012, FAO, 2010, IPCC, 2004). Compared to the mitigation potential

[8] The effect of plantation of perennial crops is not constant overtime. For this action, it is considered that a maximum stock is reached after 20 years for soil and for biomass. This explains the slight decrease of the sink after 2045.

per ha of the action (i.e. 43 tCO_2), the average cost-benefit of the action is estimated to be \$29 to \$88/tCO_2eqv.

3.1.6.5 Co-benefits

Beyond the climate impacts, the main co-benefits of this measure come from:

- Some biodiversity benefits through the potential increase in pollinator effect for some cover crops;
- Improved soil health through the maintenance of vegetative cover for longer periods of the year, with increased organic matter supply, improved water infiltration, increased water holding capacity and nutrient supply benefits;
- Improved livelihoods through crop diversification and increased income.

3.1.7 Development of agroforestry and hedgerows

3.1.7.1 Rationale

The greenhouse gas balance of agricultural land can be improved by increasing the storage of biomass or soil carbon in an organic way by the development of woody biomass and by a greater restitution of organic matter in the soil. So generally, this action consists of planting trees in agricultural plots in large arable or herbaceous crops (agroforestry), or at their periphery (hedgerows). This is similar to a forest plantation even though the carbon stocks in the forest are generally much higher than those observed with agroforestry or hedgerow systems.

3.1.7.2 National circumstances

According to the Land Degradation Report of 2018, one of the main goals of the Republic of Armenia is to stop the degradation of cultivated land and to apply agroecology based on conservation measures and modern "biological" technologies.

Currently, about two thirds of all agricultural land is in different stages of degradation resulting from several factors such as the fact that owners of small settlements do not apply modern methods of cultivation, crop rotation is not very frequent, fertilizers are poorly applied, the use of pesticides is not rationalized, water management and irrigation are not optimized, etc. Therefore, it seems relevant to extend the measures for a better management of agricultural practices by disseminating modern methods of agriculture and forestry and by promoting in particular the cultivation of hedges and agroforestry.

3.1.7.3 Potential target

The carbon stocks in the biomass of hedgerows or agroforestry for agricultural land depend strongly on the type of hedgerows/trees and the density of hedgerows/trees. These types of practices are not well documented in Armenia, but in landscapes with many hedgerows, the most classically practiced ones generally correspond to hedgerow lengths between 60 and 100 meters per agricultural hectare. Taking an average value of 80 meters per hectare, this corresponds to an equivalent of 0.20 m^3 of wood per meter of hedge, or an additional stock of about 5 tC/ha of converted agricultural area. This value can be considered quite similar for agroforestry systems. Thus the average impact of the action carried out on 1 ha allows the reduction of 15 tCO2 over 20 years, i.e. 0.76 tCO_2 per hectare and per year for 20 years.

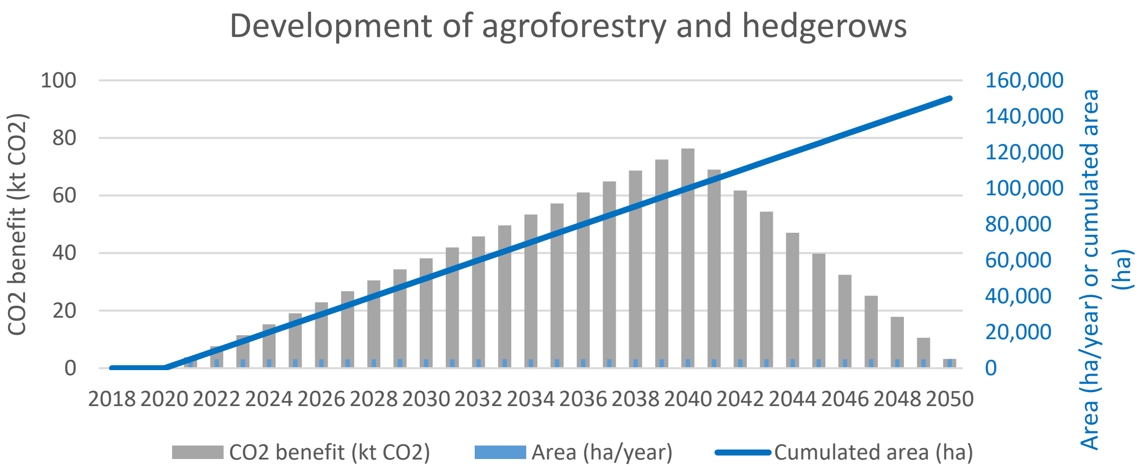

Figure 8: CO_2 benefit, area per year and cumulated area for Development of agroforestry and hedgerows

Assuming that this measure can be extended to 5,000 ha per year for 30 years, we arrive at a cumulative surface of 150,000 ha. Under these conditions, the overall impact of this action would reduce emissions by 1,163 ktCO2 over the entire 2018-2050 period[9].

3.1.7.4 Cost-effectiveness

The costs of implementing hedgerows or agroforestry vary greatly depending on the type of practices implemented. They essentially include the initial investment to convert the surfaces. By crossing several data sources and different practices, the range of costs can be estimated between $250 and $1000 per hectare (UNCCD, 2018, McKinsey, 2013, Harutyunyan, 2012, Thuy, 2019, FAO, 2012, FAO, 2010, IPCC, 2004). Thus, considering a mitigation potential of around 5tC per hectare, the co-efficiency of this measure is between $31 and $125/tCO2.

3.1.7.5 Main co-benefits

Overall, the co-benefits of this measure are the same as the previous measure and could come from the following:

- Some biodiversity benefits through the potential increase in pollinator effect for some tree crops;
- Improved soil health through the maintenance of tree cover and hedgerows, with increased organic matter input, improved water infiltration, increased water holding capacity, and nutrient input benefits;
- Improved livelihoods through crop diversification and increased income from agroforestry activity.

3.2 OTHERS POSSIBLE MEASURES

Other possible actions were explored and analyzed during this study, in line with those explicitly mentioned in the IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security and Greenhouse Gas Flows in Terrestrial Ecosystems. However, due to their low mitigation potential in the national context, they have not been detailed.

The list below includes all relevant actions that were explored but not prioritized:

[9] The effect of this action (development of agroforestry and hedgerows) is not constant overtime. The sink decreases strongly after 2040 due to high rates of wood removals put on these lands to participate to wood fuel supply.

- Prevention of soil sealing on cropland;
- Prevention of grassland conversion to cropland;
- Sawn wood harvest regulation;
- Increase amount and lifespan of harvested wood products;
- Limitation of wood losses during harvesting;
- Prevention of forest fire events;
- Prevention of other natural disturbances (windfalls, snow breaks);
- Non cultivation of organic soils;
- Limitation of exports of biomass from crops (residue harvest or burning);
- Development of non-till farming techniques;
- Increase biomass productivity of crops;
- Adjustment in the choice of cultivated species;
- Introduction of more intermediate crops, intercrops, grassed strips;
- Increase of manure application;
- Optimization of water management;
- Restoration of degraded soils (acidified, eroded, salty soils) on cropland;
- Spreading of "inert" carbon (e.g. Biochars);
- Limitation of peat extraction.

3.3 SUMMARY OF LULUCF MITIGATION OPPORTUNITIES

All the actions discussed are presented in the following table with the possible effects for each and the area concerned. All these actions are not treated independently of each other and to conduct an effective policy, it will be necessary to prioritize them according to their mitigation potential but also to their cost-effectiveness (see 2.4).

Table 4 Summary of LULUCF mitigation actions

N°	Long name	Mitigation 2018-2050 ($ktCO_2eqv$)	Area 2018-2050 (ha)	Mitigation 2018-2050 (tCO_2eqv/ha)
FOR1	afforestation on grasslands	-43 579	250 000	174
FOR2	restoration of degraded forests	-6 761	200 000	34
AGR11	optimization of grassland management	-4 063	500 000	8
AGR1	plantation of perennial crops	-1 689	50 000	34
LUC3_G	prevention of deforestation to implement crops	-1 534	7 000	219
AGR2	development of agroforestry and hedgerows	-1 163	150 000	8
FOR3	optimization of forest management practices	-742	30 000	25
FOR5	fuelwood harvest regulation	-663	100 000	7
LUC3_C	prevention of deforestation to implement crops	-471	2 000	235
LUC2	prevention of grassland conversion to cropland	-366	20 000	18
AGR6	increase biomass productivity of crops	-358	100 000	4
AGR9	increase of manure application	-336	10 000	34
AGR5	development of non-till farming techniques	-322	100 000	3
OTH1	Limitation of peat extraction	-270	489	552
AGR4	limitation of exports of biomass from crops	-233	18 000	13
AGR8	introduction of more intermediate crops, intercrops, grassed strips	-109	30 000	4

N°	Long name	Mitigation 2018-2050 (ktCO$_2$eqv)	Area 2018-2050 (ha)	Mitigation 2018-2050 (tCO$_2$eqv/ha)
FOR8	prevention of forest fire events	-105	3 000	35
AGR10	optimization of water management	-51	8 000	6
LUC1	prevention of soil sealing on cropland	-1	30	32
FOR4	sawnwood wood harvest regulation	0	0	0
FOR6	increase amount and lifespan of harvested wood products	0	0	0
FOR7	limitation of wood losses during harvesting	0	0	0
FOR9	prevention of other natural disturbances (windfalls, snow breaks)	0	0	0
AGR3	non cultivation of organic soils	0	0	0
AGR7	adjustment in the choice of cultivated species	0	0	0
AGR12_C	restoration of degraded soils (acidified, eroded, salty soils) on cropland	0	0	0
AGR12_G	restoration of degraded soils (acidified, eroded, salty soils) on grassland	0	0	0
AGR13	Spreading of "inert" carbon (e.g. biochars)	0	0	0

In addition, the figure below calculates the trajectory of each land cover through 2050 based on the identified measures and policies. The light areas highlight the amount of each area impacted by the measures.

The figure confirms that the proposed measures provide an ambitious set of mitigation actions leading to action on about 50% of the land cover by 2050. But the figure also confirms that this is technically feasible because the land areas subject to action are compatible with the total land areas of the territory.

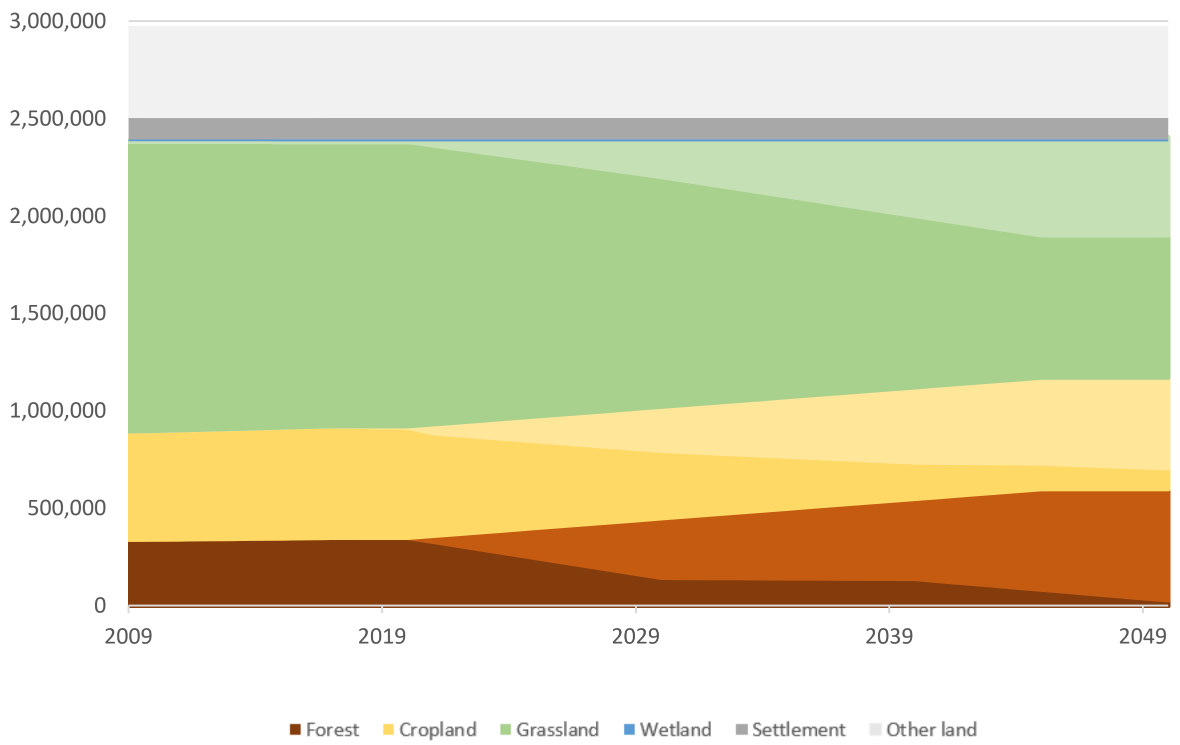

Figure 9 : Areas per category of land use (ha) with area concerned by actions (lighter color)

While the analysis conducted during this study confirms the great potential of integrating the LULUCF sector into the national mitigation effort, it also highlights the great challenge from a political and institutional point of view given the magnitude of the efforts required to achieve the described objective.

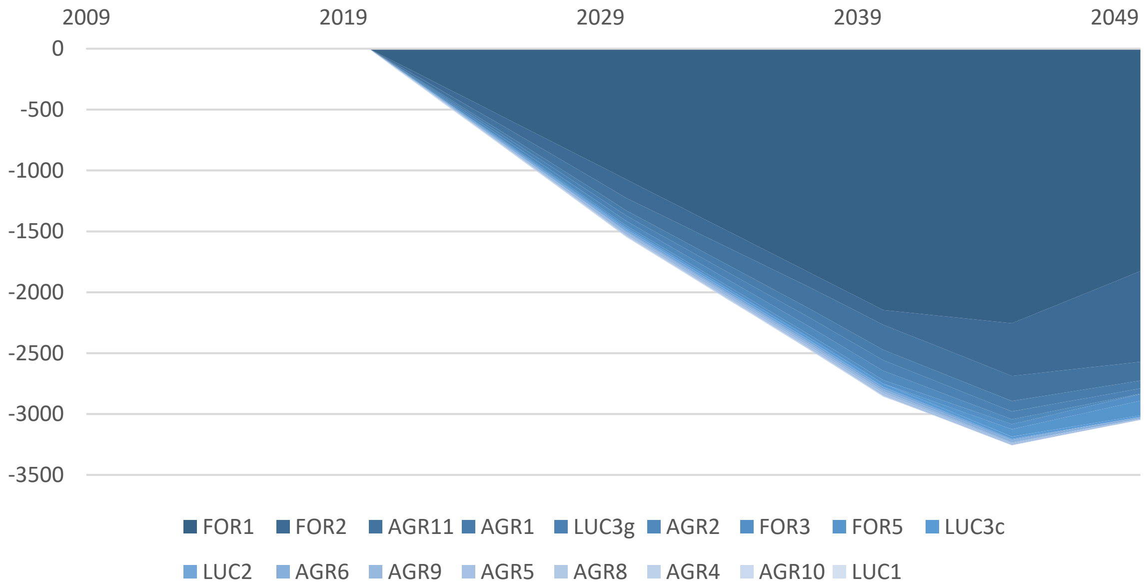

Figure 10 : Cumulated benefit of actions (kt CO_2eqv)

3.4 MARGINAL MITIGATION COST CURVE

Based on the preliminary cost estimates of each proposed measure, the following graph summarizes the magnitude of the cost-effectiveness of each measure and profiles the mitigation curve of the LULUCF sector in Armenia.

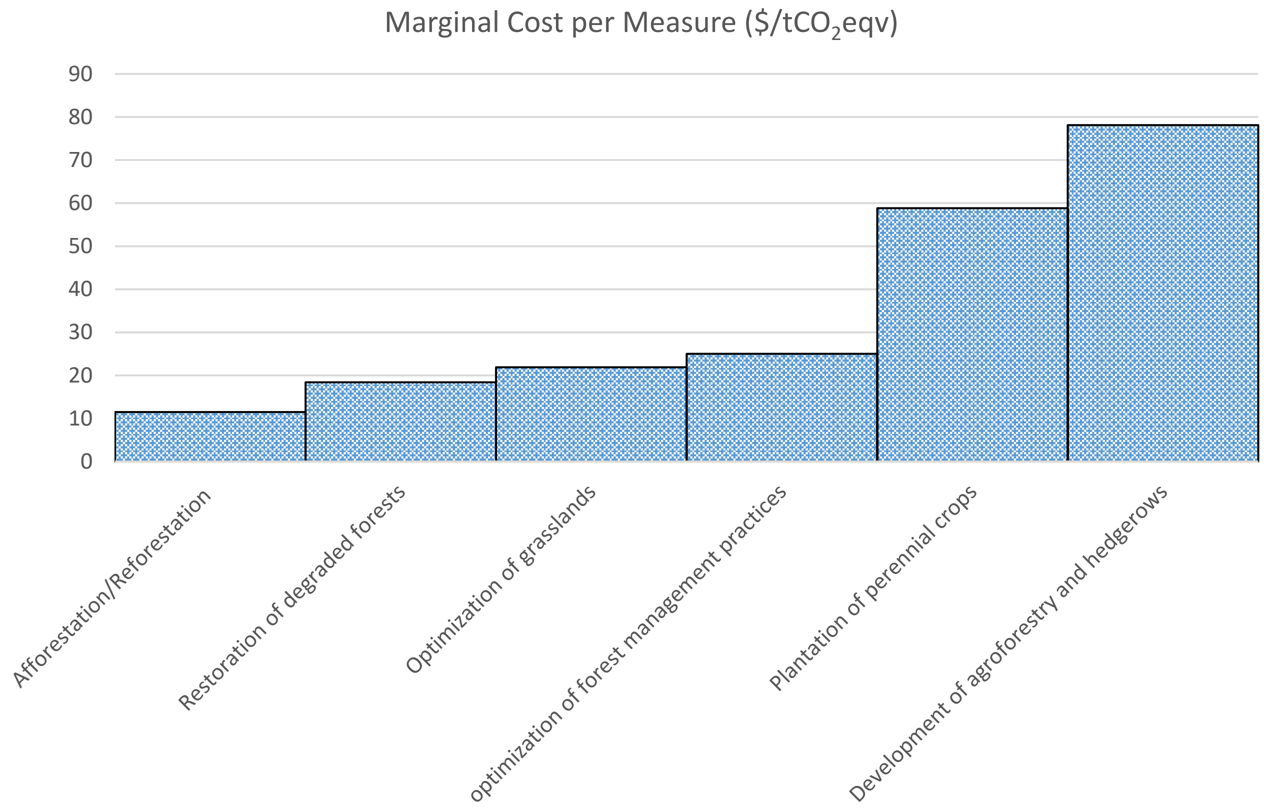

Figure 11 : Marginal costs per measure ($/tCO$_2$eqv)

With an estimated cost per tCO2 range of less than $10 to about $80 per unit of tCO2, this figure overall confirms that the LULUCF sector is a cost-effective mitigation opportunity and a competitive solution compared to other industrial sectors such as transportation or construction (McKinsey, 2013).

Also comparing to the global carbon price market, the measures taken in the LULUCF sector in Armenia seem relevant. Indeed, the High Level Commission on Carbon Prices has estimated that carbon prices of at least USD 40-80/tCO2 by 2020 and USD 50-100/tCO2 by 2030 are needed to cost-effectively reduce emissions in line with the temperature maintenance goals of the Paris Agreement.

It is also apparent from the figure above that forestry mitigation activities are the most cost-effective compared to agricultural activities, either because some forestry activities are less costly to implement (e.g., avoided deforestation) and/or because measures in the forestry sector offer significant potential for emissions reductions per unit of implementation resulting from a higher carbon stock in forests than in other land covers.

3.5 ADDITIONAL RECOMMENDATIONS

For the actions targeted in this note to be effectively implemented, it is strongly recommended that at least two additional national frameworks be put in place that are currently lacking:

- A national land monitoring system;
- A sustainable and incentive-based financing framework.

3.5.1 National Land Monitoring System

Armenia does not currently have a national land monitoring system based on remote sensing data. In the current inventories, data have been compiled from administrative documents called "Land Balance". Their use in the inventory does not appear to be totally reliable and the estimation of land use changes is sometimes lacking. For example, all estimates of forest condition over the years are based on the last national inventory of 1993 and the annual flow of marketed timber (Republic of Armenia, 2020a). This lack of updated data and, in particular, the absence of spatial mapping to track land use limits knowledge and understanding of land use trends and land use changes.

As part of the implementation of any mitigation measure, and particularly in the LULUCF sector, it is necessary to closely monitor the land areas where the measures and associated actions will take effect. Land monitoring is always a challenge for the LULUCF sector inventory, but today there are many ways to collect information, available data based on ground observations, and very accurate tools for land use and land cover mapping.

In addition, the last forest inventory is outdated (1993). This limits the knowledge of the actual state of forests in Armenia. To take appropriate measures regarding forests, it is strongly recommended to conduct a new forest inventory. In addition, the establishment of a forest monitoring system will allow for regular monitoring of forest changes and subsequent evaluation of the impacts of future activities to be implemented in Armenia.

A national land monitoring system seems to be essential today to have an adapted and reactive policy to territorial dynamics, and thus in the long term for an efficient mitigation policy. Favoring satellite imagery monitoring systems, which are very accessible today, allows a cost-effective monitoring policy.

3.5.2 Appropriate Sustainable Financing Framework

The effectiveness of most of the actions identified will in fact depend on the degree of ownership by local actors and some of them will require direct involvement and investment by the private sector. Indeed, the actions listed in this note are ambitious and to ensure the feasibility of implementation and sustainability of mitigation activities, it is strongly recommended to put in place an appropriate legislative and institutional framework providing adequate financial status and sufficient incentives to achieve the objectives. Under these conditions, it is particularly relevant to find institutional arrangements that promote and support public-private partnerships and initiatives.

Incentive mechanisms may include national mechanisms based on fees or subsidies for climate services provided by private actors, as well as a national carbon credit market or carbon taxation mechanisms, for example. It may also be appropriate to set up specific investment funds that can be funded by private and public actors. In addition, particularly for the preparation and investment stages, multilateral financing and other international funds (Green Climate Fund, Adaptation Fund, Global Environment Facility, etc.) can be used. Finally, to ensure medium and long-term financing, the possibility of introducing new market instruments such as green bonds or debt-for-nature swap instruments could be studied.

The main objective of setting up a sustainable financing framework for the specific case of the LULUCF sector is to limit the risks of non-permanence of mitigation efforts and to provide sufficient incentives for certain sectors, such as forestry, which usually suffers from a lag between actions taken and effects achieved.

Of course, the LULUCF sector is not the only one concerned by these requirements and the national financing framework should be developed in an integrated manner across all sectors as part of a national mitigation policy.

CONCLUSION

Clear signals can be highlighted from this study. The most impactful mitigation actions are afforestation and restoration of degraded forest ecosystems. They are also the ones that seem to have the lowest costs per unit of reduction. In addition to the action of capturing carbon, forests are likely to return co-benefits to society in terms of wood supply, but also for the preservation of soil and biodiversity.

In this study, a specific focus was carried on wood supply, and actions were calibrated to ensure that wood supply was not abruptly stopped which seems unrealistic. The wood supply is presented in the

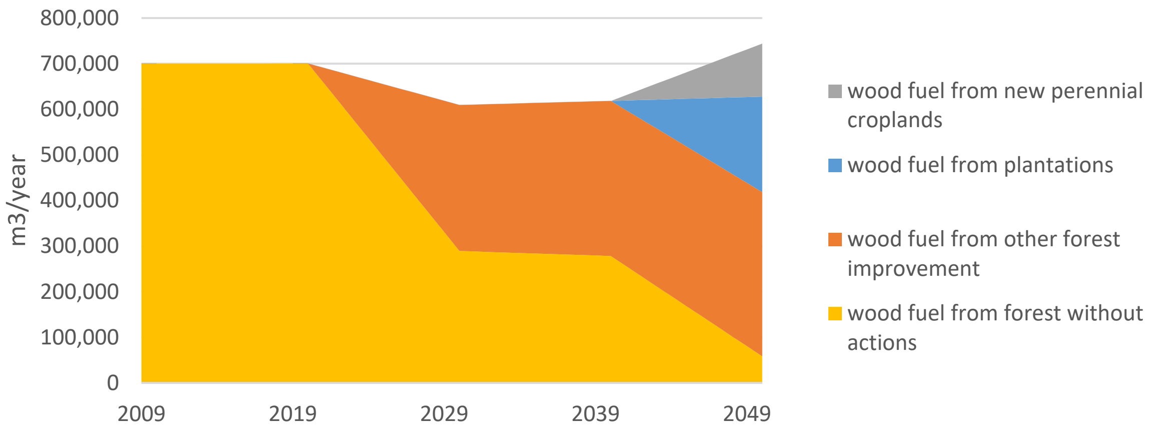

Figure 12 : Wood fuel supply (m3/year) according to origin of wood

In agriculture, apart from planting orchards and hedgerows, which are like forestry measures but on a smaller scale, agricultural actions have less significant effects. This is because in agriculture most actions relate to soil organic matter. Soil organic matter stocks are difficult to increase significantly. Secondly, it must be recognized that precise knowledge of carbon stocks in soils and associated agricultural practices are essential to carry out a detailed analysis of potentials. This knowledge remains low in Armenia, like in most countries. Even highly complex models cannot accurately reproduce soil carbon changes in agricultural land. It even more the case with very simplified model like the one used for this study based on IPCC 2006 guidelines.

The work carried out during this study confirms that the land monitoring systems (area monitoring by remote sensing technologies, forest inventories) are insufficient in Armenia. Although, they are essential for orientating actions to reduce emissions. Good land monitoring requires financial resources but also skilled people and institutional arrangements. It may be a long process, but new technologies help a lot to fast these evolutions.

The implementation of actions on the territory is subject to strong constraints, in particular short-term issues, but also land ownership issues, the direction of which cannot be decided centrally. It is therefore necessary to encourage the emergence of incentive systems to guide public and private actors towards these planting and restoration actions. These systems can take the form of fees, but more effectively subsidies for planting (forestry or agricultural) or for better-yielding household equipment that allows a reduction in wood energy consumption.

This study covers a broad scope that cannot replace more detailed studies carried out by local actors. It also recalls that the land sector remains complex to monitor and the associated actions represent significant challenges for all stakeholders.

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