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

TECHNICAL REPORT

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

Technical report

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The objective of this report is to identify technical opportunities for the GHG emissions' reduction and removal enhancement, to provide recommendations on long-term targets of the GHG emissions/removals in the country's Land Use, Land Use Change and Forestry sector. The report relies on the earlier delivered background study findings, reviews similar efforts in the broader region and details on mitigation actions and strategy.

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Summary

This report analyses the current situation of the inventory with a view to facilitating the estimation of possible emission reduction actions, provides an overview of actions proposed by neighboring countries and international bodies, and then an action-by-action analysis of the emission reduction potential in Armenia.

It can be noted that the inventory of the LULUCF sector remains a challenge for the country, particularly because of the lack of monitoring of forest areas, which are lands with significant carbon fluxes. But this also applies to agricultural land, particularly grasslands, where the level of degradation is considered important and for which monitoring carbon stocks in the soil would be very beneficial.

At the level of neighboring countries, the NDCs (nationally determined contributions) indicate that afforestation and restoration of degraded land are the main actions, the international literature goes a little further by covering more broadly all the possibilities for action, but it remains that the main actions remain afforestation and the restoration of degraded ecosystems.

The analysis of the actions is carried out by first estimating the impact of each of the actions per unit of area concerned and then the potential is estimated by assuming of an implementation area. This is a forecasting work in which the actions are not independent, some actions can influence others, this is particularly the case for all actions impacting land that can produce wood.

It appears that afforestation is by far the most capable action to reduce greenhouse gas emissions. This action is based on a very ambitious position with regard to the afforestation surface. Secondly, restoration actions are also important in forests and meadows, with equally ambitious assumptions regarding the areas concerned.

The afforestation of 250,000 ha would generate an additional sink of 44 $MtCO_2$ for the entire period 2018-2050 and the restoration of 200,000 ha of forest would generate a reduction of emission around 7 MtCO2 for the entire period 2018-2050.

All cumulative actions, a sink of 62 MtCO2 is obtained over the period 2020-2050 with an annual maximum sink reached around 3,000 ktCO2eq/year.

Introduction

General context

The Government of Armenia is currently supported by the EU4Climate Programme, to take actions against climate change. This support, funded by the European Union, is implemented by the United Nations Development Programme (UNDP).

Among all sectors involved in limiting climate change and developing resilience, the Land Use, Land Use change and Forestry (LULUCF) sector and the agriculture sector have a central role to play. As stated in the Paris Agreement, these sectors contributions are essential to reach the long-term climate mitigation and adaptation objectives, especially to achieve carbon neutrality.

In the EU, a new regulation (2018/841) now ensures that accounted emissions from land use are entirely compensated by an equivalent removal of CO_2 from the atmosphere through action in the sector ("no debit" rule).

Aim of the assignment

Citepa and ONFi have been selected to conduct the mission for the assessment of Land Use, Land Use Change and Forestry Sector Potential in Achieving Climate Change Mitigation Objectives in Armenia. The overall objective of this assignment is to assess the potential for enhancing removals by sinks and reducing anthropogenic emissions by sources in the LULUCF sector. Once this detailed analysis of the current situation is drawn, recommendations on policies and measures feasible from economic, social and environmental point of view will be developed.

5 deliverables are to be produced in this context:

- A background report
- A technical report
- A policy note
- A workshop
- A final package of recommendations and guidance

Aim of the Technical report

The present document is the second deliverable of the assignment. It aims to identify technical opportunities for greenhouse gas emissions' reduction and removal enhancement in the LULUCF sector in Armenia.

It considers feedback and comments received within the duration of the study.

1. LULUCF inventory and baseline

To evaluate the potential of mitigations actions, it is essential to have a clear picture of existing emissions and removals. For example, to know how much deforestation can be reduced it is necessary to know how big the current deforestation is and could be in the future.

Thus, it is essential to build a baseline and forecast emissions and removals for the period of prospective. These projections will help to propose relevant mitigations actions. For example, if an activity is naturally disappearing, it is not necessary to propose additional mitigation actions.

It is also necessary to have such projections to distinguish the impact of mitigation actions and the impact of business-as-usual activities. It is especially relevant for LULUCF sector where long term dynamics may be strongly linked with past activities. For example, the forest sink for 2050 is much linked with current forest activities and not to current forest emissions and removals. The forest balance may be very different in 2050 even with a constant forest activity for the period 2020-2050, just because of natural forest dynamics.

Considering these issues, national LULUCF inventory was replicated, for this study to implement a consistent baseline and ensure a consistent application of mitigation actions. To do so some features of the national inventory were simplified, modified, or corrected. The following paragraphs present the baseline, they are based on latest national inventory report but with several adjustments.

1.1 Land monitoring

Land monitoring is always a challenge for the LULUCF sector inventory, there are many ways to collect information on this land monitoring but all present management difficulties. Today we see very accurate products of land use mapping, but to be useful for the calculation of inventories we need to know the history of these lands. Estimating a coherent and realistic historical time series remains very complex. Most often long-time series products from satellite imagery are still at low resolution, so they often lack a lot of land use changes. In contrast, techniques based on field surveys generate many biases and tend to overestimate changes.

For Armenia's current inventories, data were compiled from administrative documents called "Land Balance". Their use in the inventory does not seem completely reliable and the estimated changes in use are sometimes lacking.

In addition, there appear to be inaccuracies in the integration of this data into the IPCC tool computing software. For example, the land use change matrix indicated in the national inventory report is presented below, it differs from the matrix provided in the IPCC tool for the same year for all boxes with the character "?". Then in the IPCC tool it is necessary to inform both the 20-year and annual matrixes and there are inconsistencies between the values provided for the 20-year matrix and the 1-year matrix.

These difficulties are often encountered and do not always have major impacts, but for example the changes between grasslands and croplands are very different depending on whether one considers the 20-year matrix provided in the tool or the annual data summed up over 20 years which is strange.

Table 1 : 20 year Matrix from 1997 to 2017 (ha) - in the 2017 NIR

⮣	Forest	Cropland	Grassland	Wetland	Settlement	Other land	Initial Area
Forest	349 000					27	349 027
Cropland	940,4	572 620	122		**?**	1 467 **?**	575 149
Grassland		**?**	1 459 627		**?**		1 459 627
Wetland				9 853			9 853
Settlement		**?**			110 306		110 306
Other land		**?**				470 298	470 298
Final Area	349 940	572 620	1 459 749	9 853	110 306	471 792	2 974 260

Table 2 : 20 year Matrix from 1997 to 2017 (ha) – in the IPCC tool

⮣	Forest	Cropland	Grassland	Wetland	Settlement	Other land	Initial Area
Forest	349 000					27	349 027
Cropland	940,4	570 092	122		580	1 428	573 162
Grassland		2 451	1 459 627		616		1 462 694
Wetland				9 853			9 853
Settlement		7			108 910		108 917
Other land		70				470 337	470 407
Final Area	349 940	572 620	1 459 749	9 853	110 106	471 792	2 974 060

Table 3 : 20 year Matrix from 1997 to 2017 (ha) – from annual Matrixes reported in the IPCC tool

⮣	Forest	Cropland	Grassland	Wetland	Settlement	Other land	Initial Area
Forest	349 941	4	0	0	0	352	350 296
Cropland	0	571 299	3 677	0	0	7 495	582 471
Grassland	0	1 250	1 453 761	0	0	16 978	1 471 989
Wetland	0	0	0	9 853	0	0	9 853
Settlement	0	67	0	0	110 306	0	110 373
Other land	0	0	2 312	0	0	446 967	449 279
Final Area	349 941	572 620	1 459 750	9 853	110 306	471 792	2 974 260

To avoid dealing with these difficulties, it is proposed to use as a reference inventory the monitoring of land obtained by researchers from Landsat images in 2020 (Buchner, 2020). This work makes it possible to have a homogeneous estimate over the period 1987-2015 which is very practical.

Nevertheless, it is necessary to recall that these type of data remains uncertain and with rather low resolution because it is made with Landsat images (resolution of 30m). some changes may be undetected. But it presents a consistent time series since 1987 which is very useful to implement LULUCF inventories.

Table 4 : 20 year Matrix from 1997 to 2017 (ha)

⮣	Forest	Cropland	Grassland	Wetland	Settlement	Other land	Initial Area
Forest	322 019	2 607	6 161	122	48	50	331 007
Cropland	2 275	491 005	57 694	2 577	304	26	553 880
Grassland	25 575	78 995	1 395 895	0	0	0	1 500 464
Wetland	33	10	0	7 154	0	0	7 198
Settlement	37	1	0	0	109 953	0	109 991
Other land	2	3	0	0	0	471 716	471 721
Final Area	349 941	572 620	1 459 750	9 853	110 306	471 792	2 974 260

It can also be pointed out that in many calculations, the stock variation method is used, and that this method can be based either on annual matrix or on 20-year matrix. In the IPCC tool for example deforestation is calculated from the annual matrixes for biomass. As part of this project, it was chosen to harmonize the calculation mode and keep the matrix for 20 years for all calculations by stock variation. This does not have much impact on the result and gives smoother results.

For the baseline, land use changes observed on between 2010-2015 were extrapolated to 2050, which is of course a rough assumption, but this is supposed not to be a big trouble as far as the change rates are low according to these matrixes.

Many assumptions were necessary to fulfil a LULUCF inventory and the uncertainty on results will remain very high as long as the monitoring will not be reliable for forest ground monitoring and land use monitoring.

1.2 Soil and litter assumptions

For the calculations, the value of 33 tC/ha was selected for forest (IPCC default value for soils with low activity clay under cool temperate dry climates), and lower values were assumed for grasslands (28 tC/ha) and croplands (25 tC/ha) (by using respectively the parameter FLU = 0.85 and FLU = 0.75 in IPCC equation 2.25). These stocks are low and are maybe underestimated, results would be significantly different by choosing soils with high activity clay (50tC/ha instead of 33tC/ha).

These gradation between stocks is not directly linked with IPCC default value but reflects a likely effect of land use changes considering other sources that indicate lower values of carbon stock under coppice, grasslands, and cultivated areas compared to forest in Armenia. (Rhoades, 2008).

The stocks of carbon in soils are thus not very different in the estimates between the different land uses but it must be noted that litter is high with 28tC/ha under forest and zero for other land uses.

1.3 Forestland

Forest parameters are often the main drivers in LULUCF inventories. This is particularly important for Armenia, where forest inventory data are lacking over the recent period and which has large gaps between the different (official) data sources.

To consider relevant reduction actions you need to have a fairly accurate idea of inventory results. For the forest, the current inventory uses a low growth value (compared to international references) and a harvest volume that would sometimes be nearly 20 times underestimated. For the year 2017 for example, the figures used in the inventory are 2,922 m3 of commercial wood and 70,246 m3 of energy wood (NIR, 2017). According to another recent source (GEF-UND, 2020), the values for 2016 would be 33,900 m3 of commercial wood and 848,000 m3 respectively for energy wood. This is a huge gap that obviously changes the carbon balance of forests.

Following exchanges with Armenian stakeholders, it was chosen to use the growth factor that is proposed in the national inventory for Armenian forests (1.5 m3/ha/year) although this value is very uncertain. The possibility to switch to the value proposed by other studies giving a higher value of 2.9 m3/ha/year (Thuresson, 1999) was finally abandoned due to missing arguments.

On the other hand, it was chosen, after exchange with Armenian stakeholders, to use a specific estimate for wood harvest and not the values proposed in the inventory that seem underestimated. The value of 700,000 m3/year of harvest was used for all years. It can also be noted that the dataset provided by the GEF UNDP report gives much higher wood removal for the recent years but the entire time series is also very uncertain.

Emissions from forest fires were corrected because CO2 emissions from forest fires were considered missing.

All other parameters are conserved from national inventory report.

1.4 Croplands

With the change in land use matrixes, the results for land becoming culture are significantly modified, due to changes between grasslands and crops that affect large areas. This is a first difference with the national inventory.

Then the calculation for stock variation of soil seems wrong in the official inventory, grassland converted to cropland generate sinks of carbon, which is unlikely.

Finally, the calculation for perennial crops was corrected to be in line with the IPCC guidelines. The calculations proposed in the 2017 national inventory (2020 edition) are wrong for perennial crops. Perennial crops are possible options as reduction techniques, so they must be integrated properly.

All mistaken calculations were corrected.

All other parameters are conserved from national inventory report.

1.5 Grasslands

As with crops, with the change in land use matrix, the results for land becoming grasslands are significantly modified, due to changes between grasslands and crops that affect large areas.

In the official inventory the calculation for stock variation of soil seems also wrong, cropland conversion to grasslands has no impact on soil.

All mistaken calculations were corrected.

All other parameters are conserved from national inventory report.

1.6 Wetlands

The changes in the matrix have some impacts on emissions and removals.

For peat extraction areas, the calculation in the national inventory is not changed. It should be noted that emissions from peat extraction appear to be rising very sharply and are reaching significant levels for Armenia. Unfortunately, the emissions of CO_2 and N_2O are very directly related to the activity, the associated reduction techniques mainly concern reductions in activity.

1.7 Settlements

In the land balances used in the national inventory, artificialization was rather low and the new land monitoring gives even lower levels of artificialisation. It is possible although surprising, artificialisation is so common all around the world, even when population is not growing.

In the calculations for the inventory a large part of crop converted settlement do not have impacts on soil which is strange. And 39 ha of 295 ha converted have a gain of carbon for soil. And biomass losses are not considered because annual matrixes are not correctly filled.

Similar doubtful assumptions are made for grassland converted to settlements.

All calculations were revised.

1.8 Other lands

For inter-use conversions, the change in the matrix has some impacts on emissions and removals.

Soil calculations are doubtful: a gain of carbon in soil is considered when forest are converted to other lands.

All calculations were revised.

1.9 Harvested wood products

No calculation was made for the national inventory. In the recalculation of the inventory this category is kept as it is. No calculation is performed. I could be improved but accurate data on wood harvest would be necessary.

1.10 LULUCF synthesis

The inventory for Armenia was recalculated to maximize the likeliness of mitigation actions. The following table presents the result of the inventory considering these changes and a comparison with latest calculations for the NIR.

Differences are especially due to the choice of much higher wood removal levels, higher growth factor and the use of a different set of land use matrixes.

Table 5 : LULUCF inventory recalculated with new assumptions and corrections

kt CO2e	2010	2011	2012	2013	2014	2015	2016	2017
Forest (including forest fires)	84	69	58	51	49	49	44	72
Cropland (including burning)	129	126	122	119	116	112	112	112
Grassland (including 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**

Table 6 : LULUCF inventory in latest official communications (ipcc tool related to NIR,2017)

kt CO2e	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**

To estimate the mitigation actions, it is not essential to precisely know the actual emissions of the inventory, but it allows to change the scale of application of some actions. For example, land monitoring shows more deforestation than the national inventory report, so the mitigation of deforestation may be greater. This is particularly true for fuelwood harvest, which are very low in the national inventory, when they appear to be very high due to informal harvests. The action to reduce informal harvest is therefore much more impactful with this new inventory.

2. Calculation methods for mitigation actions

All the calculations rely on a calculation framework that allows to estimate the LULUCF inventory, for both past years (in line, if possible, with existing past inventory reports) and future years (projections). This same framework is used to calculate LULUCF emissions by sources and removals by sinks and to calculate emissions and removals associated with specific mitigation actions.

Mitigation potentials are estimated for each year; and can be summed to assess short term and long-term potential.

Most of the mitigations are calculated thanks to a common calculation framework proposing a stock variation method for all carbon pools and/or a gains and losses method for biomass. For each mitigation action two periods are defined: the first 20 years, and the years after. For each action, all parameters used in calculations are available in Annex II.

They are presented as follow:

Table 7 : Table format of parameters used to simulate actions

Pool	Parameter	Unit	First 20 yrs	After 20 yrs
Biomass	Average annual above-ground biomass growth (Gw)	t.dm/ha		
Biomass	Root to shoot (R)	no unit		
Biomass	C content	tC/td.m		
Wood removal	Amount of wood removed	m3/yr		
Wood removal	BCEFR	t d.m/m3		
Wood removal	Root to shoot (R)	no unit		
Wood removal	C content	tC/td.m		
Wood removal	total amount in C	tC/yr		
Fuel wood	Amount of wood removed	m3/yr		
Fuel wood	BCEFR	t d.m/m3		
Fuel wood	Root to shoot (R)	no unit		
Fuel wood	C content	tC/td.m		
Fuel wood	total amount in C	tC/yr		
Biomass	Evolution of stock	tC/yr		
Biomass - Initial	Above ground biomass	t.dm/ha		
Biomass - Initial	Ration of below-ground biomass to above-ground biomass	no unit		
Biomass - Initial	Carbon fraction	tC/td.m		
Biomass - Initial	Resulting initial	tC/ha		
Biomass - Final	Above ground biomass	t.dm/ha		
Biomass - Final	Ration of below-ground biomass to above-ground biomass	no unit		
Biomass - Final	Carbon fraction	tC/td.m		
Biomass - Final	Resulting final	tC/ha		
Biomass	Evolution of stock	tC/yr		
Litter - Initial	Stock	tC/ha		
Litter - Final	Stock	tC/ha		
Litter	Evolution of stock	tC/yr		

Pool	Parameter	Unit	First 20 yrs	After 20 yrs
Deadwood - Initial	Stock	tC/ha		
Deadwood - Final	Stock	tC/ha		
Litter	Evolution of stock	tC/yr		
Soils - Initial	Stock ref	tC/ha		
Soils - Initial	F - land use / Classic	tC/ha		
Soils - Initial	F - management / Classic	tC/ha		
Soils - Initial	F - input / Classic	tC/ha		
Soils - Initial	Resulting initial	tC/ha		
Soils - Final	Stock ref	tC/ha		
Soils - Final	F - land use / Classic	tC/ha		
Soils - Final	F - management / Classic	tC/ha		
Soils - Final	F - input / Classic	tC/ha		
Soils - Final	Resulting final	tC/ha		
Soils	Evolution of stock	tC/yr		
Biomass + Litter + Deadwood + soils	Evolution of stock	tC/yr		
	Emissions/removals associated	**kt CO2/yr**		

3. Overview of mitigation actions at international level

3.1 Special report on Land from IPCC

Mitigation actions are highly dependent on country specific situations, but most of them are well known and appropriate in many countries. Considering the IPCC special report on climate change and lands1, the main LULUCF mitigations actions are linked 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).

The following mitigations actions are explicitly mentioned by the IPCC:

- Afforestation, reforestation
- Tree planting on degraded land
- Reducing deforestation and forest degradation
- Natural vegetation restoration
- improved and sustainable forest management
- Carbon storage in harvested wood products
- Agroforestry
- Improved management of cropland and grazing lands
- Management options that reduce vulnerability to soil erosion and nutrient loss
- Green manure crops
- Cover crops
- Crop residue retention

1 Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

- Reduced/zero tillage
- Maintenance of ground cover through improved grazing management
- Application of certain biochars can sequester carbon
- Use of varieties and genetic improvements for heat and drought tolerance.
- improved fertiliser management

The IPCC special report on land also mentioned many essential messages, among them:

- Carbon sequestration in soil or vegetation, such as afforestation, reforestation, agroforestry, soil carbon management on mineral soils, or carbon storage in harvested wood products do not continue to sequester carbon indefinitely.
- Sustainable forest management can maintain or enhance forest carbon stocks, and can maintain forest carbon sinks, including by transferring carbon to wood products, thus addressing the issue of sink saturation.
- Many land-related responses that contribute to climate change adaptation and mitigation can also combat desertification and land degradation and enhance food security.

The IPCC special report on land presents a very comprehensive scheme on actions and their effects on the different challenges (Mitigation, adaptation, desertification, degradation, food security).

	Response options based on land management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Agriculture	Increased food productivity	L	M	L	M	H	—
	Agro-forestry	M	M	M	M	L	●
	Improved cropland management	M	L	L	L	L	●●
	Improved livestock management	M	L	L	L	L	●●●
	Agricultural diversification	L	L	L	M	L	●
	Improved grazing land management	M	L	L	L	L	—
	Integrated water management	L	L	L	L	L	●●
	Reduced grassland conversion to cropland	L	—	L	L	- L	●
Forests	Forest management	M	L	L	L	L	●●
	Reduced deforestation and forest degradation	H	L	L	L	L	●●
Soils	Increased soil organic carbon content	H	L	M	M	L	●●
	Reduced soil erosion	←→ L	L	M	M	L	●●
	Reduced soil salinization	—	L	L	L	L	●●
	Reduced soil compaction	—	L	—	L	L	●
Other ecosystems	Fire management	M	M	M	M	L	●
	Reduced landslides and natural hazards	L	L	L	L	L	—
	Reduced pollution including acidification	←→ M	M	L	L	L	—
	Restoration & reduced conversion of coastal wetlands	M	L	M	M	←→ L	—
	Restoration & reduced conversion of peatlands	M	—	na	M	- L	●

	Response options based on value chain management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Demand	Reduced post-harvest losses	H	M	L	L	H	—
	Dietary change	H	—	L	H	H	—
	Reduced food waste (consumer or retailer)	H	—	L	M	M	—
Supply	Sustainable sourcing	—	L	—	L	L	—
	Improved food processing and retailing	L	L	—	—	L	—
	Improved energy use in food systems	L	L	—	—	L	—

	Response options based on risk management	Mitigation	Adaptation	Desertification	Land Degradation	Food Security	Cost
Risk	Livelihood diversification	—	L	—	L	L	—
	Management of urban sprawl	—	L	L	M	L	—
	Risk sharing instruments	←→ L	L	—	←→ L	L	●●

Options shown are those for which data are available to assess global potential for three or more land challenges.
The magnitudes are assessed independently for each option and are not additive.

Key for criteria used to define magnitude of impact of each integrated response option

		Mitigation *Gt CO2-eq yr⁻¹*	Adaptation *Million people*	Desertification *Million km²*	Land Degradation *Million km²*	Food Security *Million people*
Positive	Large	More than 3	Positive for more than 25	Positive for more than 3	Positive for more than 3	Positive for more than 100
Positive	Moderate	0.3 to 3	1 to 25	0.5 to 3	0.5 to 3	1 to 100
Positive	Small	Less than 0.3	Less than 1	Less than 0.5	Less than 0.5	Less than 1
	Negligible	No effect	No effect	No effect	No effect	No effect
Negative	Small	Less than -0.3	Less than 1	Less than 0.5	Less than 0.5	Less than 1
Negative	Moderate	-0.3 to -3	1 to 25	0.5 to 3	0.5 to 3	1 to 100
Negative	Large	More than -3	Negative for more than 25	Negative for more than 3	Negative for more than 3	Negative for more than 100

Variable: Can be positive or negative — no data — na not applicable

Confidence level
Indicates confidence in the estimate of magnitude category.
H High confidence
M Medium confidence
L Low confidence

Cost range
See technical caption for cost ranges in US\$ tCO_2e^{-1} or US\$ ha^{-1}.
●●● High cost
●● Medium cost
● Low cost
no data

Figure 1: Potential global contribution of response options to mitigation and other challenges (IPCC report on lands, 2017), *continued from the previous page*

3.2 European union

As part of the Paris Agreement, the parties to the Convention have submitted specific nationally determined contributions (NDC) outlining ambitions in terms of reducing GHG emissions. Among the submissions of all parties, the European Union’s one is important because it brings together all the countries of the Union with a relatively strong ambition.

The following figure shows the number of actions identified at the union level by major area.

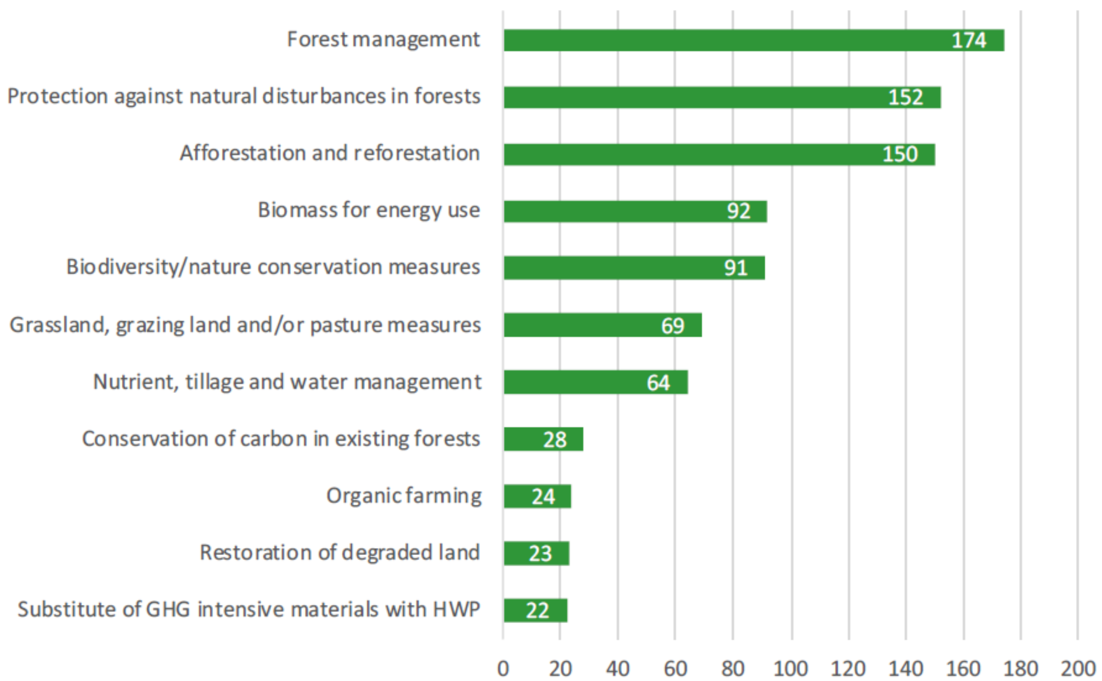

Figure 2 : Number of measures and policies reported per area of LULUCF action (Source IEEP, 2017 duplicated in brochure LULUCF)

Unsurprisingly, forest actions are the most numerous because of the importance of these lands in the LULUCF inventories of the EU member states, but we can also note the importance of conservation measures and agricultural improvement practices.

Organic farming also appears, it can indeed have important advantages especially due to the importance of organic fertilization for this agriculture. The overall greenhouse gas balance of the different production methods (conventional, organic…) remains difficult to analyze because its results differ according to the follow-up indicators chosen.

We can also highlight the issue of biomass for energy that appears in many actions at European level. This is not surprising because EU has high ambitions in terms of use of renewable energy and therefore potentially wood. But at the same time, EU is aware of the precautions to be taken in terms of increasing wood removals from European forests. Very large timber harvests can penalize the standing capitalization of forests and thus the European forest sink. The dilemma between the use of wood and forest sinks is at the heart of EU policies.

3.3 Mediterranean and neighbouring countries

The NDC are easy indicators on the relevant mitigation actions that are proposed by countries, all NDC are available on UNFCCC website (https://www4.unfccc.int/). To evaluate the relevancy of mitigation actions proposed for Armenia, it is interesting to have a look on a few neighbouring countries.

Georgia

In the geographical zone Georgia is the country which provide the most details on actions for LULUCF. The Georgian Government prioritizes three options for climate change mitigation activities in forestry sector:

(a) establish Sustainable Forest Management (SFM) practices;

(b) conduct afforestation/reforestation and assist natural regeneration; and

(c) expand the protected area.

Unconditional commitment Georgia is committed to:

- Strongly support CO_2 reduction in one pilot area, the Borjomi-Bakuriani Forest district (currently the only forest district where carbon emissions have been quantified) by at least 70% between 2020 and 2030, by strengthening law enforcement and introducing SFM practices. It is estimated that this measure will lead to an overall emission reduction of at least 1 million tonnes of CO_2 over a period of 10 years in this district covering 45,000 hectares;
- Implement afforestation/reforestation activities on already identified 1,500 ha of degraded lands by 2030;
- Assist natural regeneration of forests through different silvicultural methods on 7,500 ha by 2030 in order to restore natural forest cover.

Conditional commitment

- In case of external financial and technical support, the country commits itself to afforest/reforest up to a total of 35,000 hectares, as well as supporting relevant activities to assist natural regeneration in identified areas needing afforestation / reforestation until 2030; If Georgia receives substantial financial and technical support for the development of forest inventories and remote sensing, as well as the development of internationally recognized practices for SFM and carbon monitoring for the identified forest districts 8 (covering up to 250,000 ha of forest lands) the country commits itself to support the sustainable management of forests with estimating measures leading to an overall carbon sequestration up to 6 million tons of CO_2 on these lands over a period 2020-2030. These forest lands include the forest district of Akhmeta (covering up to 70,000 ha) where the first set of locality/site-specific criteria and indicators (C&I) for SFM will be selected/tested and implemented. The objective is to gain relevant expertise for further development of the C&I for SFM in the rest of identified forest lands to achieve the nation-wide development of SFM practices, thereby support the carbon sequestration; With financial support from international sources to set up an adequate infrastructure and assure effective planning for management of the additional protected areas during 2020-2030, country commits itself to expand the protected area from 0.52 million ha to 1.3 million ha (about 20% of Georgia’s territory) comprising at least 1 million ha of forests.

Azerbaijan

The NDC mentioned very shortly a few actions for LULUCF.

Land Use, Land-Use Change, and Forestry (LULUCF) sector Plant new forest areas, water and land protecting forest strips (windbreaks), urban and roadside greenery as well as further improve the management of pastures and agricultural lands.

Turkey

Turkey listed main ambitions.

Agriculture:

- Fuel savings by land consolidation in agricultural areas
- Rehabilitation of grazing lands
- Controlling the use of fertilizers and implementing modern agricultural practices
- Supporting the minimum tillage methods

Forestry:

- Increasing sink areas and preventing land degradation
- Implementing Action Plan on Forestry Rehabilitation and National Afforestation Campaign

Lebanon

Lebanon presented a slight longer list.

Forestry and agriculture Overarching objective: Towards sustainably managed forest resources, safeguarded ecological integrity, and economic and social development for the benefit of present and future generations. This will be achieved through the implementation of the National Forest Programme including, among others:

- Raising tree nurseries’ productivity.
- Planting of trees.
- Implementing the forest fire fighting strategy.
- Rehabilitating irrigation canals.
- Promoting Good Agricultural Practices through the support of organic farming and obtaining quality certificates.
- Applying forest integrated pest management.
- Developing an early warning system for agricultural pests and climatic conditions.

Maroc

The NDC remains very short although Maroc has very intense policies in favor of agriculture and forestry.

For the agricultural and forestry sectors, only CO_2 sequestration in biomass was accounted for. For the agricultural sector, the emissions and GHG sequestration recorded are those related to the sequestration of CO2 in the arboriculture and course development programs linked to the "Plan Maroc Vert" (olive tree, fruit trees, argan trees, cacti, fruit shrubs, date palms development). For the forestry sector and other land uses, the emissions and GHG sequestration recorded are only those related to reforestation and reforestation, route management and sylvopastoral management, improved furnaces and forest climate risk management (e.g., fires and forest health).

4. Possible mitigation actions for Armenia

Considering the previous overview of existing actions, mitigations actions selected for Armenia were listed and classified into subgroups:

- Land use change actions
- Forest actions
- Agriculture actions
- Other actions

The list is certainly not exhaustive but covers most of the possible actions presented by IPCC and the different Parties to the convention. All actions may not be relevant for Armenia: they are mentioned because they were analysed to calculate their mitigation potential. Non relevant actions will not be retained at the end in the recommendations.

Actions may be dependent, but in this chapter, it was tried to estimate separately impact of different actions. Therefore, combined actions remain possible and even encouraged to maximize positive impacts on lands.

4.1 Land use change actions

The following land use change actions are prevention of radical actions which are not in favour of CO_2 removals (soil sealing (urbanisation), grassland conversion, deforestation).

4.1.1 Prevention of soil sealing (LUC1)

Principle

The loss of forest and agricultural land to artificial or urban areas (roads, buildings, etc.) leads generally to a loss of carbon due to the destruction of existing carbon stocks. This can affect both the biomass and the soil carbon pools. Urban areas may have significant carbon stocks with parks and gardens, but very often in inventories it is considered that all existing stocks are just lost with soil sealing.

Preventing soil sealing helps to conserve productive land and generally large carbon stocks.

National situation

In Armenia, artificial areas have increased of nearly 5% between 2006 and 2015 which represent more than 10 000 hectares artificialized during the period (UNCCD, 2018). Population of Armenia is rather stable and even decreasing for recent years but this trend of soil sealing is common among countries even when population is not increasing, due to the development of infrastructures and the growing of cities.

Urban spreading usually occurs in periphery of existing cities which are often arable lands. This soil sealing is an issue since it leads to the destruction of agricultural future possibilities in these zones. In Armenia, a lot of former agricultural lands are currently abandoned by agriculture. It does not mean that the losses of agricultural lands are not an important issue, because it is often the most fertile lands which are urbanized, and they cannot be replaced by low productivity lands.

Yet, soil sealing is not well tracked in the land use matrix proposed by Buchner (Buchner, 2020) where soil sealing is nearly zero.

Unitary mitigation impact

Soil sealing has a different impact depending on whether it is on a crop, a meadow, etc.

For this exercise, the following values estimated through IPCC 2006 guidelines are used: 25 tC/ha for croplands against 17 tC/ha for artificial lands.

For the soil sealing on cropland, the average impact of the action carried out on 1 ha allows the reduction of 47 tCO_2 over 20 years (2.37 tCO_2/ha/year for 20 years).

Application scale

Considering, the land use matrix, soil sealing is negligible: less than 1 hectare /year between 2010 and 2015.

It is not possible to mitigate something which does not exist, so we limit this action with 1 ha per year, for the principle and because we are not sure that this low value is very reliable. If we trust the report on land degradation (unccd,2018), this value would be more around 1000 ha/year for the period 2006-2015.

We consider that this action could be deployed on 1 ha per year for 30 years for a cumulative surface area of 30 ha.

Global mitigation impact

The overall impact of this action would reduce emissions of 1 $ktCO_2$ for the entire period 2018-2025.

4.1.2 Prevention of grassland conversion (LUC2)

Principle

Grasslands can be converted to arable land to increase short-term agricultural productivity. Here is considered the long-term conversion of historically grasslands into croplands. This is not a crop rotation involving some temporary grasslands, as these temporary grasslands are considered as a cultivation practice and reported by convention under cropland.

The conversion of grasslands to cultivated land can result in a significant loss of carbon, as soil carbon stocks under grasslands are often much higher than those observed under cropland.

Preventing grassland conversion helps to save the large soil carbon stocks generally stored under grasslands.

National situation

In Armenia, grasslands and pastures represent a large share of the country (around 50% of the country), they are mostly dedicated to extensive livestock breeding. However, most of the area of the steppes, especially the flat slopes and the valleys, have been ploughed and are being used as farmland. The rest of the steppes and even the steep slopes are used as pastures and sometimes as hayfields (CBD 2009).

Considering that, in Armenia a lot of lands are abandoned by agriculture, it is likely that there is no important pressure on pasture for conversion into arable lands.

Unitary mitigation impact

In RA report for UNCCD (UNCCD, 2016), it is mentioned that stocks in soils are about 59.7 tC/ha for grasslands while carbon stocks under crops would be 35.2tC/ha.

For this exercise, the following values estimated through IPCC 2006 guidelines are used: 25 tC/ha for croplands against 28 tC/ha for grassland.

The carbon storage that takes place when converting to grassland is generally not equivalent to the removal of carbon when converting to cropland. Nevertheless, this difference is not considered in the current estimations.

The average impact of the action carried out on 1 ha allows to save 18 tCO2/ha over 20 years (0.92 tCO_2/ha/year for 20 years).

Application scale

According to land monitoring proposed by Buchner et al (2020), approximately 3,500 hectares/year are converted from grassland to crops over the period 1987-2015. It is a classic land use change that sometimes comes from uncertainty in the monitoring of crops (grasslands may be in crop rotation). Nevertheless, the reversal of permanent grasslands is one of the major factors in the release of carbon from the soils into the atmosphere. At the same time about 4,500 hectares of crops are converted to grassland over the period 1987-2015. Over the period 1987-2015, a net flow of crops to grasslands is observed.

On the other hand, we can note that the results are different on the 2010-2015 matrix for which the balances are reversed with a net flow of grasslands to cultivation of more than 2000 ha/year over 5 years.

Considering as baseline a constant net conversion of grassland converted cropland like the one observed between 2010 and 2015, the action ambition could be to limit net conversion from grassland to cropland to zero.

We consider that this action can be deployed on 2 000 ha per year for 10 years for a cumulative surface area of 20 000 ha.

Global mitigation impact

The overall impact of this action would reduce emissions of 366 $ktCO_2$ for the entire period 2018-2050.

4.1.3 **Prevention of deforestation (LUC3)**

Principle

Deforestation is a major factor in global CO_2 emissions (LULUCF global net emissions are estimated at 5,2 $GtCO_2$ yr^{-1} and are mostly from deforestation – (IPCC, 2019)). This is easily understandable, as forests usually have very large carbon stocks, destroying them leads to the release of carbon to the atmosphere and limit the potential for absorption. Deforestation generally affects biomass and soil carbon stocks.

When forests are burned or cleared for uses such as crops, pasture, etc., the net uptake of carbon from the atmosphere by the forest stops, both in the present and for the expected lifetime of the trees.

Deforestation results in the release of the carbon stock that has accumulated, both in the trees themselves and in the forest soil. The rate of carbon release depends on how the forest is cleared and what the wood is used for: clearing for combustion or bioenergy production results in an immediate release of carbon to the atmosphere, while harvesting wood products, such as lumber, furniture, or paper, traps some carbon in the product over its lifetime, which ranges from a few years for paper to several decades for other wood products.

In Armenia, data show that in recent decades the forest has been cleared primarily for agriculture and pasture. The forests play a vital role in keeping the mountain soils intact; in Armenia, landslides, erosion and loss of biodiversity have occurred as a result of deforestation (Moreno-Sanchez and Sayadyan, 2005; Boudjikanian, 2006; MNP, 2007).

National situation

Armenia is one of the 70 low forest-covered countries, as its forests cover around 12% of the total land area. Hence the continuing deforestation of already scarce forest resources presents a significant environmental threat, combined with destroying consequences for habitats, irreversible losses of biodiversity, lost revenue of the government from the alternative benefits of the forest (e.g. tourism development) (EV, 2007).

The historical evolution of forest cover in Armenia was precisely described in different publications (Moreno-Sanchez and Sayadyan, 2005; Rhoades, 2008).

During the first half of the 20th century, deforestation increased as fuelwood was needed for industrial purposes, such as copper production. Also, forest land was cleared for agriculture in the lower elevations and for pastureland in the higher elevations (Moreno-Sanchez and Sayadyan, 2005).

Population increased markedly, up from about 720,000 people in the 1920s to almost two million by 1960. The number of settlements also increased and spread, bringing with it the need for fuel, construction materials, road networks, pasture land, and land for agriculture, which all resulted in further deforestation. Growing copper and molybdenum mining demanded large amounts of timber. Emissions from these plants and, later, chemical plants resulted in substantial levels of air pollution, which affected the health of forests throughout Armenia (Moreno-Sanchez and Sayadyan, 2005).

Logging from the 1930s to the 1950s resulted in the loss of nearly all mature trees within Armenia's forests (MNP, 2007). The intense levels of deforestation continued until the 1950s and the national forest cover had decreased to 9.6% (284,379ha) in 1941 and 8.5% (253,000ha) by the 1966 National Forest Inventory (Moreno-Sanchez and Sayadyan, 2005)

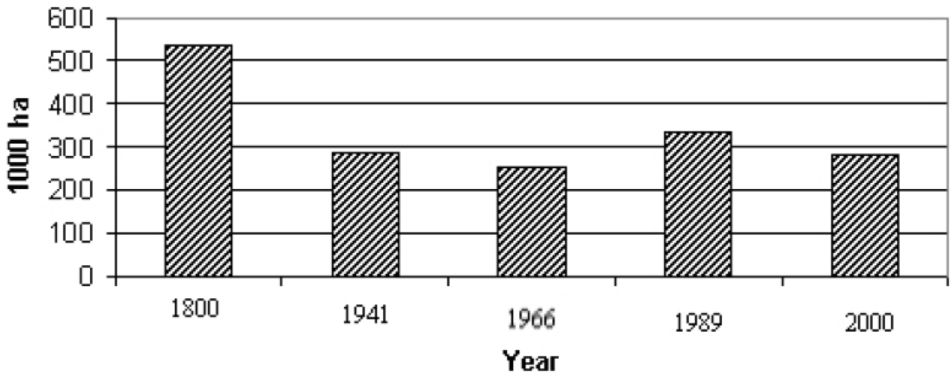

Figure 3 : Historical forest cover (Source Moreno-Sanchez and Sayadayan, 2005)

During the 1950s, as the economy improved and the unsustainable environmental practices of the last thirty years became apparent, the Soviet regime began to put in place conservation policies and management practices for Armenia's forests. It reclassified Armenia's forests into protection and conservation purposes only, prohibiting all cutting except sanitary fellings and cuttings to promote regeneration. This policy continued until Armenia's independence in 1991 (Moreno- Sanchez and Sayadyan, 2005; Sayadyan and Moreno-Sanchez, 2006).

While World War II and a post war boom in industry and agriculture resulted in further deforestation, the amount of regulated and unregulated logging greatly decreased as timber imports from Russia increased. During the Soviet regime, pine plantations have been planted around Lake Sevan, Armenia's largest body of water, and around major cities such as the capital Yerevan.

The Armenian forests were particularly damaged by unregulated and illegal logging after independence. These loggings were at first docked with a blockade and an energy crisis, and from 1996-97 it turned into an organized business, including the entire logical chain of woodworking, including timber exports. The majority of large-scale permissible and unauthorized illegal logging took place in the vicinity of major cities (e.g. Vanadzor, Ijevan, Alaverdi) as well as in forest-rural communities.

Examples of this deforestation and degradation process can be clearly seen in the basin of Lake Sevan where approximately a quarter of the forest plantations around the lake have been clear cut (Sayadyan 1997, Sayadyan 1999, Sayadyan and Nalbandyan 2002). Moreover, old high quality mixed oak and beech forests have been replaced by young low-quality coppice hornbeam forests because of high-grade cuttings for illegal timber exports to Europe, Turkey and Iran (Thuresson 2003, Moreno Sanchez 2005).

Unitary mitigation impact

Obviously, the loss of these carbon stocks by deforestation is very damaging, preventing deforestation helps to conserve the large carbon stocks generally conserved under forests.

It can also be noted that in the UNCCD (UNCCD, 2016) very high level of soil carbon stocks are noted under forest with the value of 140.85 tC/ha which is very high but of course possible in certain conditions.

While deforestation is a major concern within the Republic of Armenia, there has been little research conducted regarding the impacts it is having on Armenia's ecosystems. From soil horizon and structural characteristics, it can be estimated that 40 cm of soil have been lost in the pasture and 20 cm have been lost in the coppice compared to the forest. Soil organic carbon was also affected by deforestation and land cover change. Compared to the forest (8.2% organic carbon), both the coppice (6.3%) and the pasture (5.9%) had lower values (Rhoades, 2008).

With similar results to the coppice in relation to the forest, in the Hubbard Brook watershed clear cut experiment, Borrman et al. (1974) saw organic matter decrease by 41% in the three years following the cut. Zheng et al. (2005) found erosion to result in a loss of 69% of organic matter seven years after deforestation. Hajabbasi et al. (1997) also found forests to have higher levels of organic matter (2.50%) than deforested sites under cultivation (0.97%).

To the south of Armenia, in the Lordegan area of Iran, Hajabbasi et al. (1997) found that cutting of the native oak forests and subsequent tillage of these soils resulted in increased bulk density and decreases in organic matter, total nitrogen, and soluble ions (Rhoades 2008).

In Armenia's FRA2020 the average forest stock counting all carbon reservoirs would be 112 tC/ha for 2015.

Table 8 : Carbon pool presented in FRA 2020

tC/ha	2015
Carbon in above-ground biomass	38
Carbon in below-ground biomass	9
Carbon in dead wood	0
Carbon in litter	28
Soil carbon	37
Total	**112**

As a reminder, for the current calculation, the value of 33 tC/ha was retained for forest (IPCC default value for low activity soils under cool temperate dry climates), and lower values were assumed for grasslands (28 tC/ha) and croplands (25 tC/ha) (by using respectively the parameter FLU = 0.85 and FLU = 0.75 in IPCC equation 2.25).

The stocks of carbon in soils are thus not very different in the estimates between the different land uses but it must be noted that litter is high with 28tC/ha under forest and zero for other land uses.

For forest converted to grassland (LUC3_G), the average impact of the action carried out on 1 ha allows the reduction of 247 tCO_2 over 20 years (12.34 tCO_2/ha/year for 20 years).

For forest converted to cropland (LUC3_C), the average impact of the action carried out on 1 ha allows the reduction of 265 tCO_2 over 20 years (13.26 tCO_2/ha/year for 20 years).

Application scale

In the land use matrix (Buchner 2020), deforestation rate is around 350 ha/year for forest converted to grassland and 100 ha/year for forest converted to cropland.

Considering as baseline a constant (low) deforestation like the one observed between 2010 and 2015, the action ambition could be to stop deforestation to grassland and cropland.

We consider that this action can be deployed on 100 ha per year for cropland (LUC3_C), for 20 years, for a cumulative surface area of 2 000 ha; and 350 ha per year for grassland (LUC3_G) for 20 years, for a cumulative surface area of 7 000 ha.

Global mitigation impact

For cropland (LUC3_C), the overall impact of this action would reduce emissions of 471 ktCO_2 for the entire period 2018-2050.

For grassland (LUC3_G), the overall impact of this action would reduce emissions of 1534 ktCO_2 for the entire period 2018-2050.

4.2 Forest actions

Forests are one of the most important options for mitigation activities and are now recognized globally as such. For example, recently, Article 5 of the Paris Agreement, calls on parties to take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases [...] including forests.

Indeed, forests play an essential role in climate balance at two levels. First, forests capture carbon dioxide from the atmosphere and convert it, through photosynthesis. Secondly, forests also store significant carbon stocks in trees, soils, leaves, litter, dead wood.

Thus, a lot of forest actions can be merged into forest management actions, but it also relevant to split the types of actions to better test their impacts.

4.2.1 Afforestation or reforestation (FOR1)

Principle

The most popular possibility to act on land is afforestation (or reforestation if lands was a former forest in the last 50 years). Afforestation and reforestation actions are based on plantation but can also rather be based on natural or assisted regeneration, particularly on land abandoned by agriculture and on former forest.

The growth of trees will naturally generate a higher carbon storage in living biomass than the storage on previous land use (i.e. cropland or grassland) but soil disturbance should not be overlooked in the event of planting. It is common for a forest plantation to first result in a loss of soil carbon before replenishing a significant carbon stock under forest cover.

National situation

Approximately 90,000 ha of pine plantations were created between the 1950s and the 1980s. During the 1980s, there were almost no commercial cuts conducted within Armenia and 90% of the country's need for wood products was satisfied by imports from other Soviet Republics. As a result of these conservation measures, the forest cover rose to 11.2% (334,100ha) by the 1986-1989 National Forest Inventory (Moreno-Sanchez and Sayadyan, 2005; Sayadyan and Moreno-Sanchez, 2006; Rhoades, 2008).

Following the massive deforestation that took place during the energy crisis of 1992-1995, several periods of reforestation and afforestation measures can be distinguished: 1998-2006 (2,150 hectares), 2006-2012 (2,754 hectares) and 2013-2018 (3,303 hectares) (RA, 2020b).

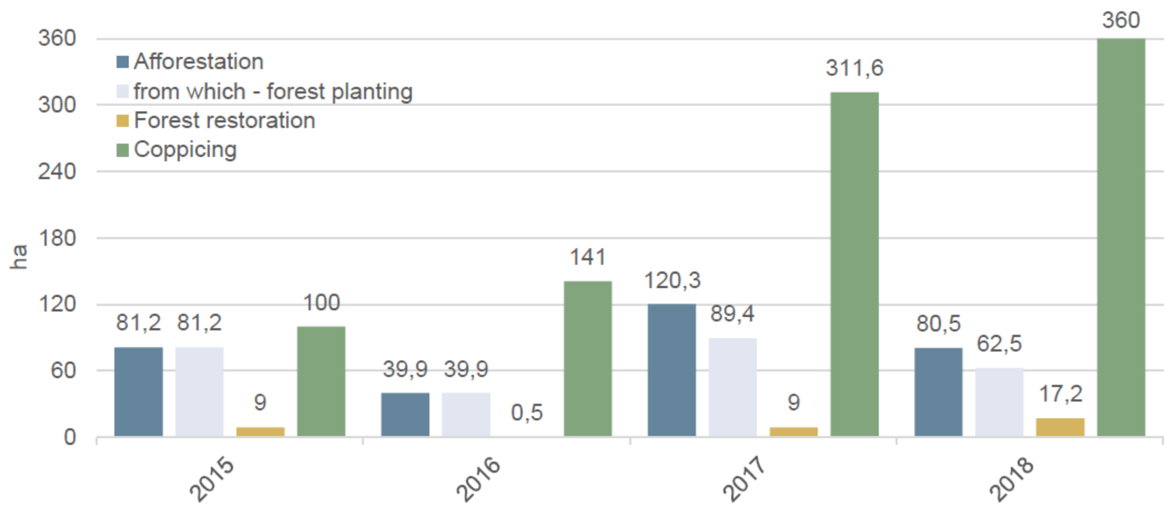

Figure 4 : Areas of afforestation, reforestation and coppicing coverage in the Republic of Armenia according to the nation 4th communication

There is a need for extensive afforestation and reforestation work to improve the condition of forests and increase the area under forest land. The development of the National Forest Program was planned for January 2020. The program shall include all the challenges that need to be addressed to expand the forest covered area to 20.1% of the RA territory by 2050. Since 2016, "Mainstreaming Sustainable Land and Forest Management in Mountain Landscapes of North-Eastern Armenia", UNDP-GEF Project (2016-2020), has been implemented involving development of management plans of three forestry branches of "Hayantar" SNCO in Tavush and Lori regions. Currently, development of management plans for three additional forestry branches is underway (RA, 2020b)

Forest plantations can be developed on degraded lands. One of the most important tasks should be afforestation of unused agricultural land, especially severely degraded, on soils with very low soil fertility. In most cases, it is necessary only to conduct afforestation and maintenance of irrigation water, especially in the first years after planting trees, it also requires the use of modern irrigation methods including drip irrigation (UNCCD, 2016).

Unitary mitigation impact

Plantation growth is very dependent on pedoclimatic conditions. And it is likely that these conditions are little fertile due to recent degradation of lands. If we consider the values proposed by the IPCC for natural forest growth and plantations (IPCC 2006) we can see that the possible range for growth is large and between 0.5 and 10 t d.m/ha/year when uncertainty ranges are considered.

This choice is based on values proposed by the IPCC for different climate, ecological zones that could be relevant for Armenia. But even IPCC values are not very consistent (growth rates are not always consistent with stocks) and the following diagrams were adapted from IPCC 2006 guidelines, they are not strictly in line with the guidance.

Table 9 : List of ecological zones defined by IPCC possibly relevant for Armenia

Id	Forest/Plantation	Domain	Ecological zone	Continent	Species
A	Forest	subtropical	subtropical steppe	Asia(continental)	undefined
B	Forest	subtropical	subtropical mountain systems	Asia(continental)	undefined
C	Forest	temperate	temperate continental forest	Asia, Europe	undefined
D	Forest	temperate	temperate mountain systems	Asia, Europe	undefined
E	Plantation	subtropical	subtropical steppe	Asia	broadleaf
F	Plantation	subtropical	subtropical steppe	Asia	coniferous
G	Plantation	subtropical	subtropical mountain systems	Asia	broadleaf
H	Plantation	temperate	Temperate continental forest and mountain systems	Asia, Europe	broadleaf
I	Plantation	temperate	Temperate continental forest and mountain systems	Asia, Europe	coniferous

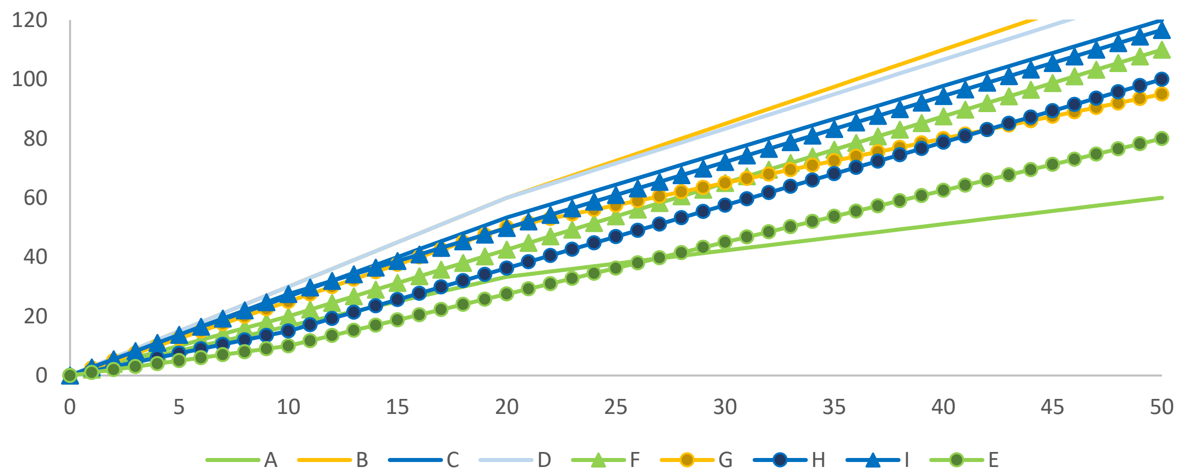

Figure 5 : Above ground biomass (t d.m/ha) (based on IPCC 2006 guidance)

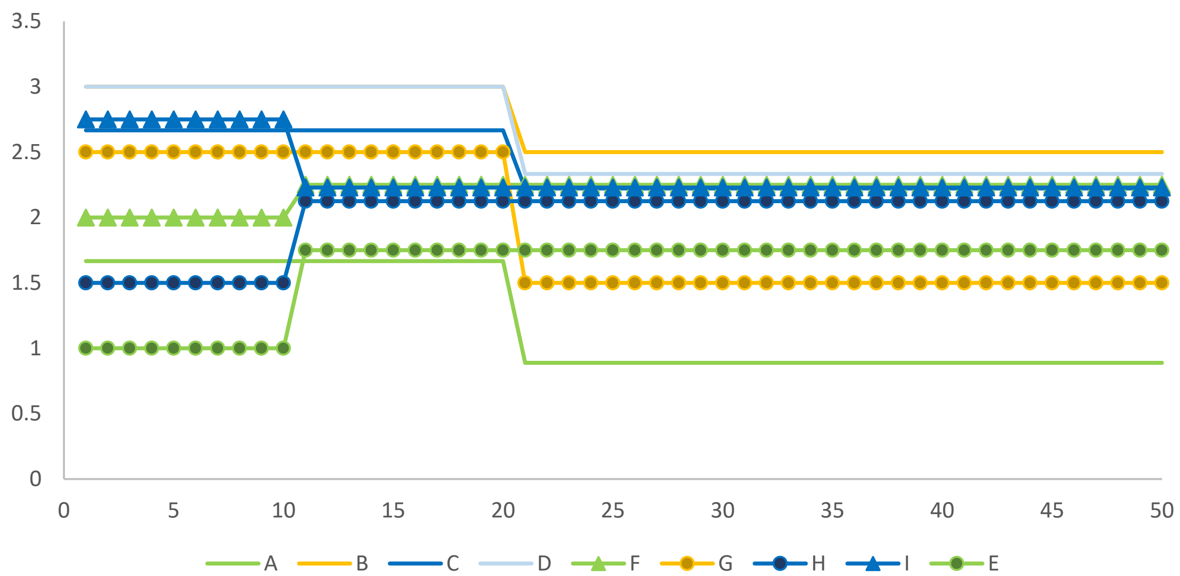

Figure 6 : Above ground biomass growth (t d.m/ha/yr) (based on IPCC 2006 guidance)

The choice of growth factors for forest planation depends on a lot of factors, first the species chosen, then of the place and finally of the chosen forestry. The values presented by the IPCC for the selected ecosystems are quite low and far below the productivity observed under the best growing conditions for which growth can easily be achieved above 10 t d.m/ha/year. In the analysis that follows it will be noted in the light of the IPCC that climate and mountain location do not correspond to situations of high fertility, the productivity presented then incorporates this parameter.

Conifer Plantation

In terms of conifer species for forest plantations we often find: pines, spruces, firs. These plantations generally target the production of timber with fast-growing species, as trees can often be harvested around the age of 50-70 years while producing significant volumes of wood over the period due to thinning. These plantations are often monospecific. For this type of plantations, we can often find a total production of 1000 m3/ha over 100 years or 10 m3/ha/year (or 6 t d.m/ha/year on average), but it was also noted that past plantations of conifers were not made with fast growing tree, but mostly with pines and juniperus with moderate growth. Considering this information and in accordance with the values proposed by IPCC, the value of 2 t d.m/ha/year was retained for both the first 20 years and the following years. Moderate levels of harvest were also considered for plantations after 20 years with an averaged harvest of 0.5 t d.m/ha/year (around 0.9 m3/ha/year). No harvest is considered for the 20 first years after planation.

Broadleaf plantations (high forest)

Other types of plantations can be preferred such as hardwood plantations for timber with oaks, beech trees, hornbeams… Plantings for these species require longer growth times and most often no wood production is possible during the first 30 years of growth. For such plantations, production would be low and slow perhaps in the order of 300 m3 over 100 years or 3 m3/ha/year (or 2 t d.m/ha/year on average). Finally, the same value of growth as conifer plantation were considered. As for conifers, moderate levels of harvest were also considered for plantations after 20 years with an averaged harvest of 0.5 t d.m/ha/year (around 0.9 m3/ha/year). No harvest is considered for the 20 first years after planation.

Broadleaf plantations (coppice)

A forestry oriented towards the production of biomass with a focus of forests in coppice was also included. For these coppices, the essences can be: oak, beech, hornbeams, chestnut… depending on the species, the cutting cycles are between 20 and 50 years for a production of about 100 to 200 m3 of wood energy per hectare. The value of 2.5 t d.m/ha/year was finally fixed for harvest for all coppices older than 20 years. Cutting in coppice involves a period of growth followed by a cut of trees before a new production cycle. This process can be carried out successively over several cycles but also ends up depleting the soil. Biomass production is strong and fast in this case but cannot be sustained for very long. In addition, on-site biomass storage is relatively low.

Table 10 : Analysis for estimating biomass growth and biomass harvest for plantations

tons d.m/ha/year	Above ground biomass growth		Above ground biomass thinning and harvest	
	<20 years	>20 years	<20 years	>20 years
Conifer Plantation	2	2	0	0.5
Broadleaf plantations (high forest)	2	2	0	0.5
Broadleaf plantations (coppice)	2.5	2.5	0	2.5
Average considering 1/3 for each option	**2.2**	**2.2**	**0**	**1.2**

Considering all possibilities presented by IPCC and the possible choices of plantations, it is proposed to retain a growth of 2.2 t.d.m /ha/year for first 20 years after plantation and 2.2 t.d.m /ha/year after 20 years with an averaged harvest of 1.2 t.d.m /ha/year after 20 years.

For litter and soil, plantations are leading to large sinks especially for litter which value is assumed to be 28 tC/ha after 20 years.

The action carried out on 1 ha generates a sink of 215 tCO_2 over 20 years (10.73 tCO_2/ha/year for 20 years) and 2.16 tCO_2/ha/year after.

Application scale

The perimeter of this action is a land use change. Some natural dynamics are converting grasslands to forestland because of abandonment of agriculture. Around 200 ha /year can be considered as a baseline.

Considering the ambitious objective of 20.5% of forest in 2050, it would be necessary to afforest or reforest nearly 250 000 ha additional.

We consider that this action could be deployed on 10 000 ha per year for 25 years for a cumulative surface area of 250 000 ha.

It must be noted that in Armenia this objective is debated and criticized, the probability to see such afforestation rate remain quite low considering all the possible obstacles (ownerships…). During the study it was proposed to reduce this objective in this simulation but, considering the feedbacks of stakeholders, this objective was kept unchanged.

Global mitigation impact

The overall impact of this action would generate a sink of 43 579 $ktCO_2$ for the entire period 2018-2050. It is a very big impact because the assumption of afforestation is very high.

4.2.2 **Restoration of degraded forests (FOR2)**

Principle

Forest degradation, such as clear deforestation, also affects climate change. In forests logging, fuel wood extraction, fires and grazing generally reduce carbon stocks faster than they can be offset naturally.

Degradation of forest is due to many causes:

- excessive harvest of wood,
- overgrazing of animals,
- low protection of young trees,
- air, water and soil pollution,
- lack of forest management and planning.

A degraded forest has a lower capacity to remove CO_2 and to store carbon on a long term. Trees are more fragile, and mortality, fires, pests and other disturbances are more likely to happen, which increases the risk of emissions and the diminution of the sink capacity.

Thus, restoration of degraded forest ecosystems may have significant potential for climate mitigation. Promoting natural forests, as opposed to monoculture tree plantations, to restore 350 million hectares by 2030, would absorb emissions equivalent to an additional 7.3% of the global total emission according to the IUCN (IUCN, 2016).

In this context, the concept of forest landscape restoration has recently emerged as a new approach to managing the overall interactions between human populations, natural resources and economic activities in a landscape. This approach is part of the International Union for Conservation of Nature (IUCN, 2016) Bonn Challenge.

National situation

Considering report on land degradation (UNCCD, 2016), it is necessary to implement measures to restore degraded forests, including areas affected by massive cuts in the nineties of the last century. In most cases, these areas are currently engaged in low value coppice stands or shrubs. In this case, it would be relevant to transform these ecosystems in the high value forest ecosystems (Unccd 2016).

Continuous grazing of large and small cattle in forests also contributes to degradation phenomena, destroying the natural regrowth of trees, which deprives the forest of the young trees (Khechoyan 2018). Therefore, forests next to local communities are frequently damaged by large and small cattle, which disturb the natural regrowth and seedlings. Therefore, large forests massifs in the North-Eastern region of Armenia without natural re-growth. To avoid such a negative phenomenon, endangered areas are needed to prevent the cattle from entering the forest. Large-scale fencing activities have been carried couple of decades ago, but many areas still need protection through fences.

In the forested areas that have no natural re-growth (because of cattle grazing or other reasons), mineralization activities can be carried out around seedling trees: this means removing the litter and mineralizing the soil at a depth of at least 8 cm. This increases the fertility of the seeds and enhances natural regrowth. Combined with fencing, such activities would be carried out around grazing areas, and burned forests areas (Khechoyan 2018).

In previously logged high-stand oak forests, an intensive growth of coppices is currently noticed. Trees grows as shrubs and these degraded areas are not walkable. In these areas it is necessary to carry out the so-called "coppicing" assistance. The principle of these works is the intersection and removal of numerous shoots that originates from the single stump. Only 2-3 well developed shoots are left on stump, which subsequently thicken, bring trees to a previous appearance, causing foliage. The forest gradually goes back to its former appearance (Khechoyan 2018).

Degradation was also found to change the species composition of seedlings and saplings in the coppice in comparison to the forest, reducing oak numbers and increasing hornbeam recruitment (Rhoades 2008).

Unitary mitigation impact

The restoration of degraded forests can take many forms, this can include physical protection of degraded areas, light 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.

It seems reasonable to estimate similar growth on restored forest that what is estimated to global forest (1.5 m3/ha/year) for the first 20 years after beginning of restoration. Higher growth is thus estimated in response to this restoration with a proposed value of 2 t d.m/ha/year (3.6 m3/ha/year) This restoration considered is partly protection against harvesting and additional degradation but also consider a reasonable harvest to facilitate regeneration or new plantations. Compared to current estimated harvest (2 m3/ha/year) the harvest on restored areas is assumed to be lower with 1.5 m3/ha/year for the first 20 years and 1 m3/ha/year after. These harvest rates are proposed in accordance with a global decrease of wood harvest. This necessary decrease is led by the development of alternatives to fuelwood and better use of fuel (see action FOR5, regulation of fuelwood). Without decreasing pressure on harvest, restoration of forest is very challenging and maybe impossible.

The areas concerned by this action won’t present a sink for the first 20 years insofar as growth and harvest rate are supposed equal for the first 20 years (1.5 m3/ha/year). Nevertheless, it represents a better situation compared to the baseline where forest are net emitters. 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. This benefit is significant considering that currently forest are net emitters.

Application scale

There is a possibility of confusion between afforestation and forest restoration, with this action we try to simulate actions on lands which are still forest but require specific action to boost productivity.

Table 11: Forest restoration by method (1995 – 2017) (ha) (source: World bank document)

	1995	2000	2005	2010	2015	2016	2017
				– hectare –			
Forest restoration	13,912	1,158	74	165	142	178	156
- of which							
seeding and planting	*1,002*	*258*	*10*	*111*	*21*	*50*	*44*
assisted natural regeneration	*12,910*	*900*	*64*	*54*	*121*	*128*	*112*

Source: Ministry of Environment Protection and Agriculture of Georgia. Forestry Agency of Adjara. Agency of Protected Areas. National Forestry Agency.

Considering the cumulative level of harvested fuel wood in recent years (7 million m3 for 10 years), the area request for restoration could be estimated considering all the area which has lost this volume of wood. If we take the assumption of 35 m3 harvested /ha, it gives 200 000 ha to be restored.

We consider that this action could be deployed on 10 000 ha per year for 20 years for a cumulative surface area of 200 000 ha.

The probability to reach such area of restoration for degraded forest seems medium, because this issue is clearly identified at national level. It is strongly linked with the possibility to reduce global harvest pressure on forest and thus to other regulations promoting other energies and efficient use of fuelwood.

Global mitigation impact

This action would allow the areas concerned to present a sink estimated at 3 436 $ktCO_2$ for the entire period. This benefit is strong considering that currently forest are net emitters. Considering a baseline with forest as net emitters the overall impact of this action reaches 6791 $ktCO_2$ for the entire period.

4.2.3 Optimization of forest management practices (FOR3)

Principle

Forest management can have different forms dependent on the type of forest and the situation of the country. In western Europe, forests are especially seen as commercial wood provider while in many countries, fuelwood is the main product of forest.

Optimization of forest management practices can include 'Sustainable Forest Management' activities. Sustainable Forest Management covers a wide range of issues that are defined by Europe and FAO as "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystem". Considering this forest management can include plantation of trees in harvested areas, choice of harvest level, frequency of harvest, choice of species, soil preparation but also conversion coppice to high forest or even coppicing if the purpose it to produce high amount of biomass.

Thus, active forest management enhances carbon uptake, both because the rate of carbon uptake slows as forests mature because of net primary productivity declines and natural mortality increases for old forest, and also because unmanaged forests increase the chance of massive carbon losses from disturbances such as fire, insects or disease infestations. Therefore, harvesting mature trees and replanting or assist natural regeneration should increase the rate of carbon absorption, as well as generating timber for wood products.

It should be noted, however, that there is no consensus on this point, especially in old-growth forests, whereas in plantations it might be different. Numerous studies have shown that mature trees absorb more carbon than younger trees, mainly because of their much higher number of leaves, which allow for greater absorption of carbon dioxide from the atmosphere. In addition, the higher carbon uptake of older trees is only partially offset by their higher mortality rate.

It must be reminded that part of this action could be the improvement of forest monitoring which is currently insufficient to make an accurate assessment of potentials.

National situation

First, since independence, the timber imports, which had been satisfying Armenia's wood product needs, decreased dramatically. A domestic black-market timber economy developed to meet the country's internal wood product needs (Moreno-Sanchez and Sayadyan, 2005). Furthermore, while Armenia now needs to manage its forests for multiple use, there were no trained personnel and no institutes within the country for educating and training foresters. During the Soviet era, forest management and education was centralized, and the nearest forestry schools were in Georgia, in Ukraine, or in Moscow. These schools focused on training and research on the coniferous production forests stretching across Siberia and the Eastern USSR; little attention was given to conservation management of mixed species deciduous forests, such as those found in Armenia (Sayadyan and Moreno- Sanchez, 2006).

Out of the 460 000 ha of forest vegetation, 334 100 ha were covered by wooded vegetation (vegetation types 1–4) at the time of the last national inventory in 1993. In 2000, 245 000 ha (or approximately 8.2% of Armenian territory) were covered by natural or planted high forests, 77 050 ha by coppice forests and the remaining 23 450 ha by dry shrub vegetation (Moreno-Sanchez & Sayadyan 2005; Sayadyan 2005a). (Sayadyan & Moreno, 2006). According to the FAO (2020), forest cover is now estimated at 310,000 hectares and 18,000 hectares of natural and planted forest respectively

Unitary mitigation impact

A large part of forest policies are dedicated to coppicing in order to provide biomass for energy. It is not really the preferred way for mitigation actions related to climate issues.

Finally, optimization of forest practices could be to convert coppice in high forest for example, but we are aware that it is maybe not easy now.

This type of forest management could increase growth of forest compared to the baseline for the period till 2050. For example, the growth could be assumed to be 1.5 t d.m /ha/year for first 20 years and then 2 t d.m/ha/year. In comparison the current situation is assumed to be 1.5 m3/ha/year (0.8 t d.m/ha/year)

It is assumed that this action is managed on non-degraded forest where high harvest rates are still possible and the value of 2 m3/ha/year is maintained.

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 forest are net emitters.

Application scale

Considering that coppicing is not a forest policy directly related to climate mitigation, the application scale of the policies is limited to a small areas.

We consider that this action could be deployed on 1 000 ha per year for 30 years for a cumulative surface area of 30 000 ha.

The probability to see improved management on forest is medium, considering the focus of national policies on forest protection.

Global mitigation impact

This action would allow the areas concerned to present a sink estimated at 448 $ktCO_2$ for the entire period 2018-2050. This benefit is significant considering that currently forest are net emitters. Considering a baseline with forest as net emitters the overall impact of this action reaches 742 $ktCO_2$ for the entire period.

4.2.4 Sawnwood wood harvest regulation (FOR4)

Principle

Commercial and industrial loggings for wood products (and not for energy purposes), such as sawnwood (furniture, construction…) can create a pressure on the forest resource if the wood cuts are not properly managed, trees are not properly selected, and if the capacity or regrowth of forest is not considered.

Harvesting wood results in a loss of carbon for the forest. This action involves limiting the harvesting of wood material, to limit forest losses. It may be noted that carbon extracted from forest can be retained for a long time from products and wood and therefore not be emitted into the atmosphere, but this impact is treated in another mitigation action on harvested wood products.

Regulation of the sawnwood wood harvests implies the definition of forest management plans that considers the possible cuts and the sustainable evolution of the forest on the long term. It also implies the regulation and monitoring of the market, from the sawmills industries to the wood products sold to the manufacture industry or directly to the consumer, to ensure the origin of the wood.

National situation

Due to the lack of availability of domestic raw material, the wood processing industry (including primary and secondary wood processing) is poorly developed in Armenia. The wood industry is highly fragmented, with small enterprises highlighting a relatively unproductive and unprofitable activity in

Armenia facing international competition (World Bank, 2020; Economy and values research center, 2007).

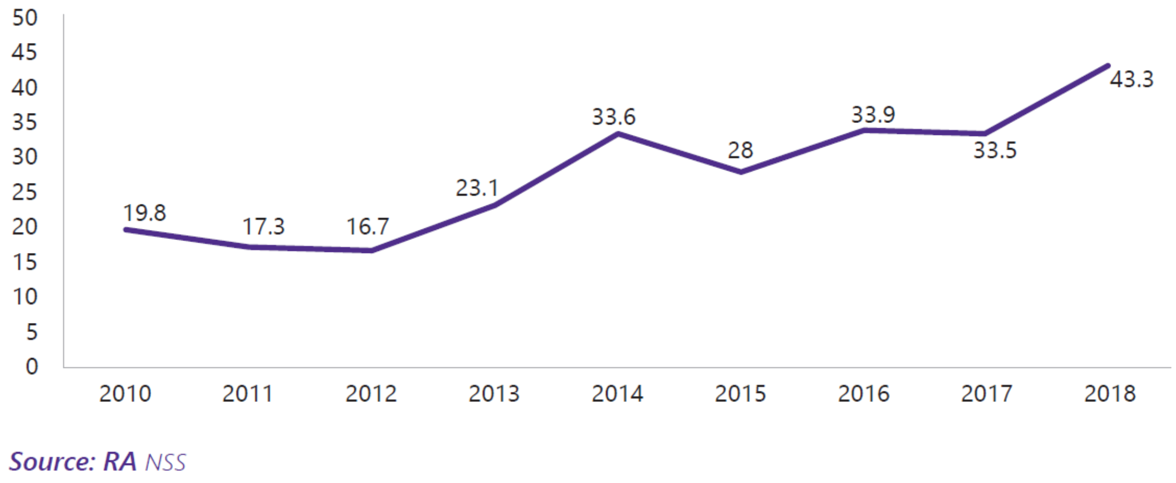

Figure 7 : Officially reported felled timber (1000 m3) according to GEF-UNDP, 2020

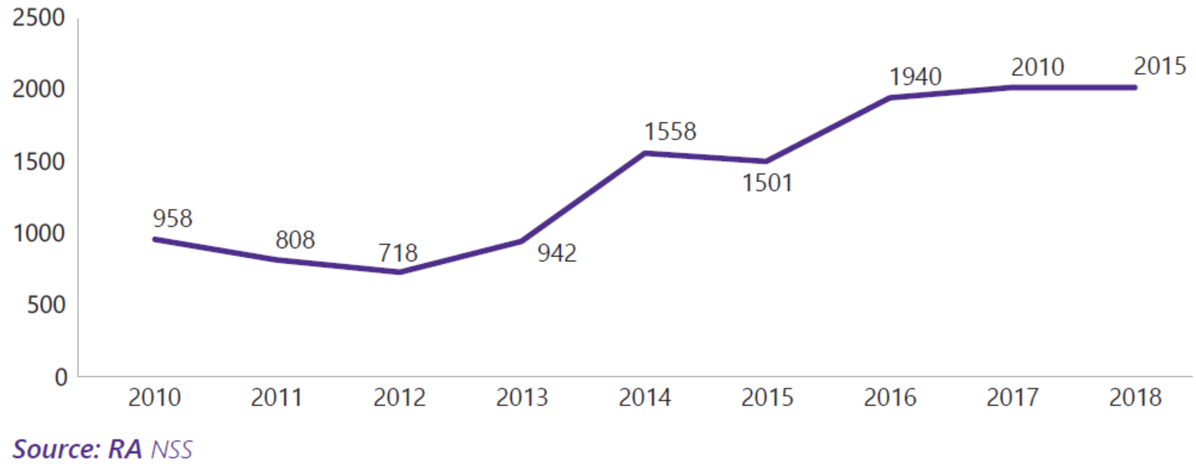

Figure 8 : Officially cutting area (ha) according to GEF-UNDP, 2020

Unitary mitigation impact

According to data from the GEF-UNDP study, 2020, the harvest rate on harvest areas is about 20 m3 per hectare cut. The implementation of this action means the avoidance of a harvest of 20m3 per hectare which amounts to the avoidance of an emission of about 25 tCO2 per hectare.

The action carried out on 1 ha allows generates a sink of 70 tCO_2 for the entire period 2018-2050.

Application scale

According to data from the GEF-UNDP study, 2020, the area cut in 2018 reaches 2015 ha with 43,300 m3 harvested. This area represents less than 1% of the forest area whose stocks are estimated in FRA2020 at more than 120 m3/ha with more than 40 million m3. This harvest is tiny compared to the standing stock (ratio 1/1000) and compared to assumed annual growth (500,000 m3/year with a growth of 1.5m3/ha/year (NIR, 2017) and nearly the double with the value of 2.9 m3/yr (Thuresson, 1999)). It does not seem appropriate to lower it. Current timber harvest activities are not seen as unreasonable pressures on forest.

We consider that this action should be deployed on 0 ha.

The volumes of commercial timber harvested are therefore low in Armenia, the main source of degradation is related to the exploitation of wood for energy wood. The activity of sawmills is underdeveloped. This situation may find it difficult to improve rapidly if we consider the very large energy harvests that are suffered from the Armenian forests, the degradation of forests prevents the production of quality wood.

Global mitigation impact

The overall impact of this action would reduce emissions of 0 tCO_2/year for the entire period.

4.2.5 Fuelwood harvest regulation (FOR5)

Principle

In Armenia, fuel wood is a significant source of energy. These traditional uses of wood for energy are important in helping to ensure access to energy for rural families and communities, but they also often have negative impacts in terms of emissions.

Because wood biomass is considered as a source of renewable energy, it can be perceived to be a carbon-neutral energy source. However, it is not, particularly regarding the combustion effect and it is commonly assumed that it produces more carbon dioxide per unit of energy than fossil fuels for example. In addition, the supply-chain from wood harvesting, processing and transporting may be significant source of emissions too.

Therefore, the only way to perceive the use of woody biomass as a carbon-neutral process, it is to consider that over time the growth of forests after harvesting absorbs the carbon dioxide emitted on combustion, corresponding to a carbon payback period. This carbon payback period varies from a few years, for sawmill wastes or forest residues, to decades or centuries for longer-lived forest residues or round wood.

In consequence, the following activities may limit the carbon emissions from fuel wood sector:

- Decreasing carbon emission per unit of energy by improving the current wood energy consumption with the use for example of improved cook stoves. The use of fuel-efficient stoves for cooking and heating at the household level and for restaurant increases charcoal use efficiency and will reduce consequently GHG emissions.
- Reducing the carbon payback period by promoting sustainable production of wood. Here, multiple options are available, such as sustainable community managed wood fuel plantations, agroforestry, or large-scale afforestation and reforestation. Indeed, a key to determining the carbon neutrality of wood energy is carbon recapturing by subsequent plantations. Wood energy should be closest to carbon neutral if the wood is drawn from a sustainably managed forest or system of growing forests, which would sequester an amount of CO2 close to or equivalent to the amount emitted in producing wood energy.

To regulate the fuelwood harvest, it is possible to improve the control on the quantity and quality of wood used for energy purposes, to ensure the sustainability of this usage. This means to have a clear picture of the quantity of fuelwood removed from forests that comes from sanitary fellings, from natural debris and mortality, and from cuts, legal or illegal.

Such a regulation is expected to help reduce the amount of fuelwood harvested and to increase the efficiency and the sustainability of the practices. Policy promoting alternative energy sources, and allowing cheaper energy rates, are also linked with this action so that less household rely on wood for heating and cooking.

National situation

The main demand for wood in Armenia comes from the consumption of firewood. The high demand is driven by the high price of alternative fuels, especially gas, in rural areas. In addition, a substantial additional demand for wood comes from the charcoal consumption of Armenian restaurants, most of which use a traditional wood-fired grilling method.

Of course, non-fossil fuel use can be benefit for climate, but wood remains a carbon containing fuel. It is not obvious that consuming fuelwood is the good option if we just talk about climate. It could be more efficient to use natural gas (although it is a fossil fuel) but in Armenia, population are using wood and especially wood from degraded forest because they do not have the economic possibilities to use gas.

Fuelwood comes from Annual Allowable Cuts (AAC), sanitary felling and imported wood, but also on an informal black-market that produces fuelwood from illegal loggings, which are the main channels of timber supply in Armenia (Economy and values research center, 2007).

Therefore, there is a high uncertainty on the actual figures of fuelwood consumption in Armenia. Several figures are available in the literature, as presented in the background report.

Considering different feedbacks during the study, it was chosen to estimate a constant level of harvest with the harvest of 700 000 m3/ha/year for the entire period since 2000.

Unitary mitigation impact

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 action FOR2 (restoration of degraded forest).

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 (action FOR1) will begin to provide wood.

The impact of this action is simulated by considering an harvested rate of 1 m2/ha/year (lower than current 2 m3/ha/year) for some areas of forest. 1 ha concerned by this action would present a sink of 12 tCO_2 for 20 years (0.60 tCO2 /year for 20 years).

Application scale

This action is directly linked with the one on restoration of degraded forest.

To limit this fuelwood harvest it is necessary to provide alternatives to the population for energy consumption. It may be by dedicating new areas to coppicing, or by importing wood from other countries, or facilitating access to natural gas consumption.

If we make the link with the actions on restoration of forest (FOR2) and optimization of forest (FOR3) we can consider that there is around 100 kha not impacted by forestry actions: 350 kha - 200 kha – 30 kha =120 kha (limited to 100 kha).

We consider that 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.

This action reflects a reduction of woodfuel harvest on the total area of forest. The probability to have policies reducing the fuelwood consumption and harvest on Armenian resource is assumed to be medium, although challenging.

Global mitigation impact

This action would allow the areas concerned to present a sink estimated at 332 $ktCO_2$ for the entire period 2018-2050. This benefit is significant considering that currently forest are net emitters. Considering a baseline with forest as net emitters the overall impact of this action reaches 663 $ktCO_2$ for the entire period.

4.2.6 Increase lifespan of harvested wood products (FOR6)

Principle

Harvest wood products (HWP) can store large amounts of carbon out of the atmosphere for a certain period, which correspond to the lifetime of the product itself. At the end of its life, a wood product can be thrown away in waste disposal site, incinerated… its carbon content is therefore returning into the atmosphere. The longer the lifespan of these wood products are, the longer the carbon is stored out of the atmosphere.

If the lifespan of the products extends this can generate a sink in the inventories on the other hand if it decreases this constitutes a source in the inventories.

Usually, in the last decades, more wood products with quick lifetimes were produced (low quality furniture, woodpanels and plywoods, paper and paperboard…) and less high quality with long lifespan were produced. Increasing the quality and lifespan of wood products, through regulation on the market, economic incentives, construction sector regulation, public purchases, etc. can help encourage the production of wood products with longer lifespan. It can also be achieved through the development of higher recycling rates of wood waste.

Increasing the use of harvested wood products can contribute to climate change mitigation by increasing lifespan of wood-products fixing the carbon and through a substitution effect on manufactured products with intensive emission materials such as concrete or brick, metals or plastics.

A consequence promoting the HWP may reduce greenhouse gas emissions and raises the value of forests that could encouraging greater investment in forest sector and indirectly better forest management practices.

However, this policy measure must be accompanied by an active sustainably managed and harvested forests to be climate efficient. For example, increasing the rotation period has the potential to increase carbon sequestration and storage in forests. Old forest stands have the highest carbon density, whereas younger stands have a larger carbon sink capacity, and forest plantations have a shorter carbon residence time. However, if HWP use leads to continued carbon storage and avoided emissions because of substitution effects, continued harvests may be preferable compared to the increase of the rotation length.

As well, the potential for carbon savings will also vary depending on the life cycle of products according to the 'cascading' approach promoting the extent to which products are recovered, reused and recycled.

This action is different form forest management promoting high quality of timber which is included in another action: the optimization of forest management.

National situation

Approximately 70,000 m3 of timber is currently harvested in Armenia on official basis, of which about 20,000 m3 are considered commercial cuttings, a harvest which satisfies only 10-14% of Armenian internal needs. Actual harvest including illegal felling, according to several estimates, is not less than 800,000 m3 per year, but essentially used as fuel wood. Since the country produces a very high quality of beech and oak hardwood, foreign exchange could be earned through forest related products - in spite of the low self-sufficiency rate - if internal needs were satisfied with lower quality lumber leaving the possibility of using higher quality wood for production of export goods (Sayadyan 2005)

Unitary mitigation impact

The Harvested wood product category is associated with the LULUCF sector but is not directly related to the land. Therefore, the modeling of this action is not associated with a surface but with quantities of wood.

If we define the action in this way: 1 m3 of firewood (short live) converted into 1 m3 of wood material with a lifespan of 10 years we get an emission delayed over time that corresponds to a reduction in emissions for inventories. The impact of this action is usually rather low except when harvested wood products have very long lifespan and when there is a strong dynamic to increase these products.

No value is currently proposed to test this action due to the expected low result.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.2.7 Limitation of wood losses during harvesting (FOR7)

Principle

The harvesting of wood in the forest can generate important losses that are not always valorized. By minimizing losses, we limit the carbon emissions of forests.

In this context, Reduced Impact Logging (RIL) is emerging as a low-cost mitigation activity with several co-benefits. It is a set of improved guidelines for timber harvesting in selectively harvested natural forests. The carbon benefits of the RIL policy have been studied at many sites.

RIL practices can provide measurable climate change mitigation outcomes without reducing timber yields and without substantially changing the operational logging system. Examples of RIL practices include improved felling for better timber utilization and waste reduction, directional felling to avoid collateral damage, skid trail planning, long-line winching, and construction of narrower haul roads.

Reduced impact logging (RIL) involves first a pre-harvest inventory and harvest planning to ensure that timber extraction activities do not jeopardize the storage and regeneration capacity of the residual stand and sustainable harvest cycles. This inventory should be reassessed periodically to determine the status of regeneration, recovery of canopy cover, and mortality rates. With this knowledge, managers can make more informed decisions for future harvesting activities, thereby improving harvesting practices over time and limiting the loss of carbon stock during harvesting.

National situation

In Armenia, the demand for wood energy is very high and it is likely that all the trees destroyed in the forest will be harvested. It is possible to assume that wood waste is minimal and operating losses are limited.

No room for progress is expected associated with this action.

Unitary mitigation impact

Not estimated.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.2.8 Prevention of forest fire events (FOR8)

Principle

Over the past decade, the effects of climate change through droughts and longer fire seasons have increased the forest fire events and made wildfires a major global problem and a significant source of emission. As climate change increases, wildfires are likely to become much more frequent and widespread, with potentially catastrophic consequences.

Thus, fire management agencies must adapt their operations and resources to respond to this increasing phenomenon. When conditions become extreme, management of firefighting activities can become insurmountable, and burned areas and timber and property losses can be significant. Thus, conduct fire hazard prevention activities in the forest is important and could significantly contribute to mitigate emissions.

Emissions from forest fires are significant, they are carbon losses and in addition to significant sources of CH_4 and N_2O. Limiting forest fires is a very relevant mitigation action.

To limit forest fires, the main actions are:

- The limitation of brush-type vegetation, dense shrubs, dead wood.
- Raising awareness among people who can practice prescribed burning of grasslands or drop residues whose impact extends beyond the intended areas.
- Setting up or maintaining a fire detection and action system to respond to fires.

National situation

Forest fire volumes increased during the last decade. In 2003 forest fires were registered only on 3.92 ha area, while in 2013 it increased to 91.575 ha. Main causes of forest fire occurrence include burning of agricultural lands of the surrounding areas. Complex landscape types, poor condition of forest road network, lack of supporting technical equipment for extinguishment of fires hinder effective implementation of fire-fighting activities (GEF UNDP 2014)

Strengthen forest protection through technical measures and new organizational measures, including prevention of forest fires, forest pollution and poaching (GEF UNDP 2020).

In addition, because of climate changes, there has been an increase in the frequency of droughty years, when under conditions of high air temperature, decreased amount of precipitation and relative humidity in some cases considerable drying of the forests, loss of trees vitality are observed. In the drought years, the frequency of emerging forest fires also significantly increases, which is explained by the duration of the dry period. In the droughty years, the frequency of emerging forest fires also significantly increases, which is explained by the extended duration of the dry period (Khechoyan 2018).

In 1998 -2010 there were 198 fires and about 1700 hectares of forest covered was burned. In recent years due to preventive measures in Armenia the damage caused by anthropogenic forest fires has decreased. The loss of forested areas for 2011-2015 made about 500 hectares (Khechoyan 2018).

Thus, according to official data, the volume of forest fires in 2017 exceeded 3000 hectares, which exceeds the volume of fires recorded over the last ten years (2191 hectares). Especially the damage caused to "Khosrov Forest" State Reserve was extremely large. According to data obtained through decoding of Seninel-2 satellite images, 1716.3 hectares were burnt down in "Khosrov Forest" State Reserve. According to a study conducted by the US Forest Service specialists, the fire mainly caused damage to juniper sparse forest and grasslands of semi-desert and mountain-steppe zones (6th report on biodiversity).

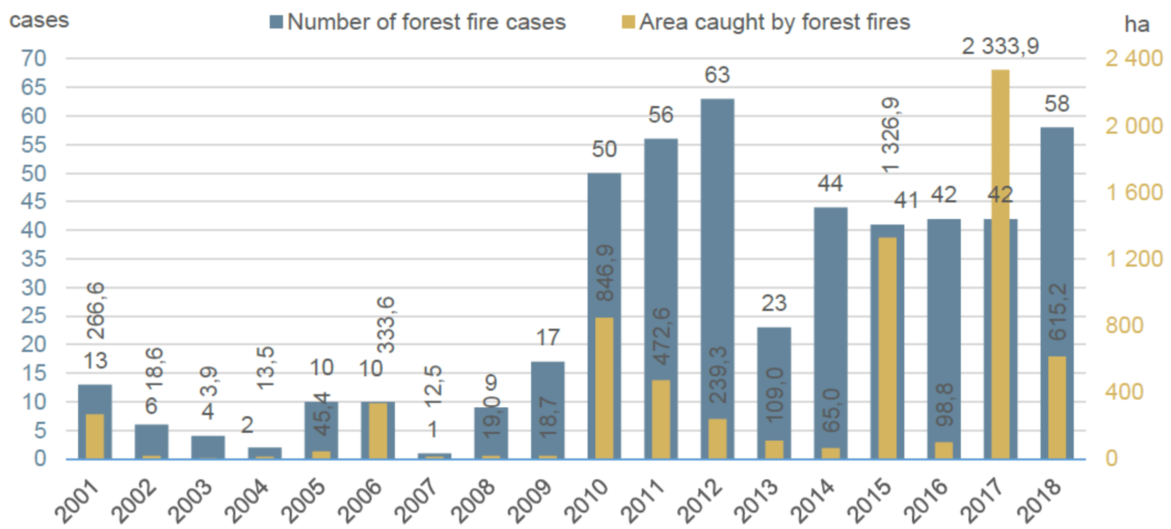

Figure 9 : Number of forest fires and areas caught by forest fires according to 4th national communication

Unitary mitigation impact

The average impact of the action carried out on 1 ha allows the reduction of 35 tCO_{2eqv}.

Application scale

We consider that this action could be deployed on 100 ha per year for 30 years for a cumulative surface area of 3000 ha.

Global mitigation impact

The overall impact of this action would reduce emissions of 105 $ktCO_2$ for the entire period 2018-2050.

4.2.9 Prevention of other natural disturbances (windfalls, snow breaks) (FOR9)

Principle

Mortality is one of the main drivers of carbon balance in forest. Mortality may be linked to many different sources (wind, snow, pests). Limiting the risk of these occurrence is linked to forest management. Mortality is important in forest where forest activities are seldom.

Thus, better management of natural diseases like insect or pest could have significant effects on forest carbon storage and sequestration rates by limiting mortality and decomposition rates of dead wood as well as preserving forest growth. Indeed, tree mortality from pest and diseases reduces forest carbon uptake and increases future emissions from the decay of killed trees. Thus, effective management of insects and diseases fighting can improve the ability of forests to fix and store carbon and thus needs to be integrated in the sustainable forest management practices.

In the case of outbreaks due to pest or diseases, carbon emissions can be avoided through sanitary felling and replanting with healthy species. A lack of intervention, with trees left to die and decay on site could result in a rapid emission of CO2 to the atmosphere.

National situation

Considering the 4th national communication of Armenia (RA, 2020b), it seems that disease pressure is increasing which may be linked with a lack of forest management. Yet it can be noted that in Europe forest is also under pressure with aridization and pest threats. It is not a specificity of Armenia.

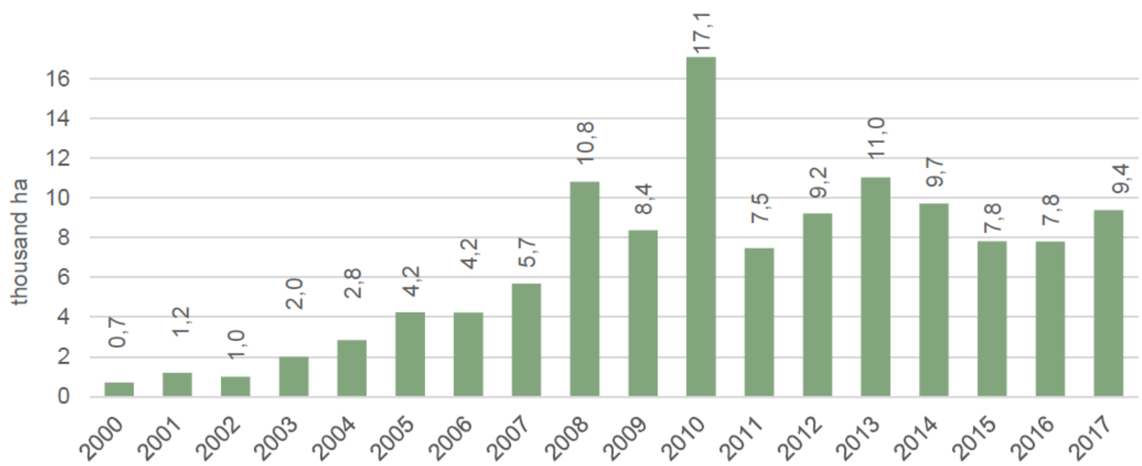

Figure 10 : Area affected with forest disease according to 4th national communication

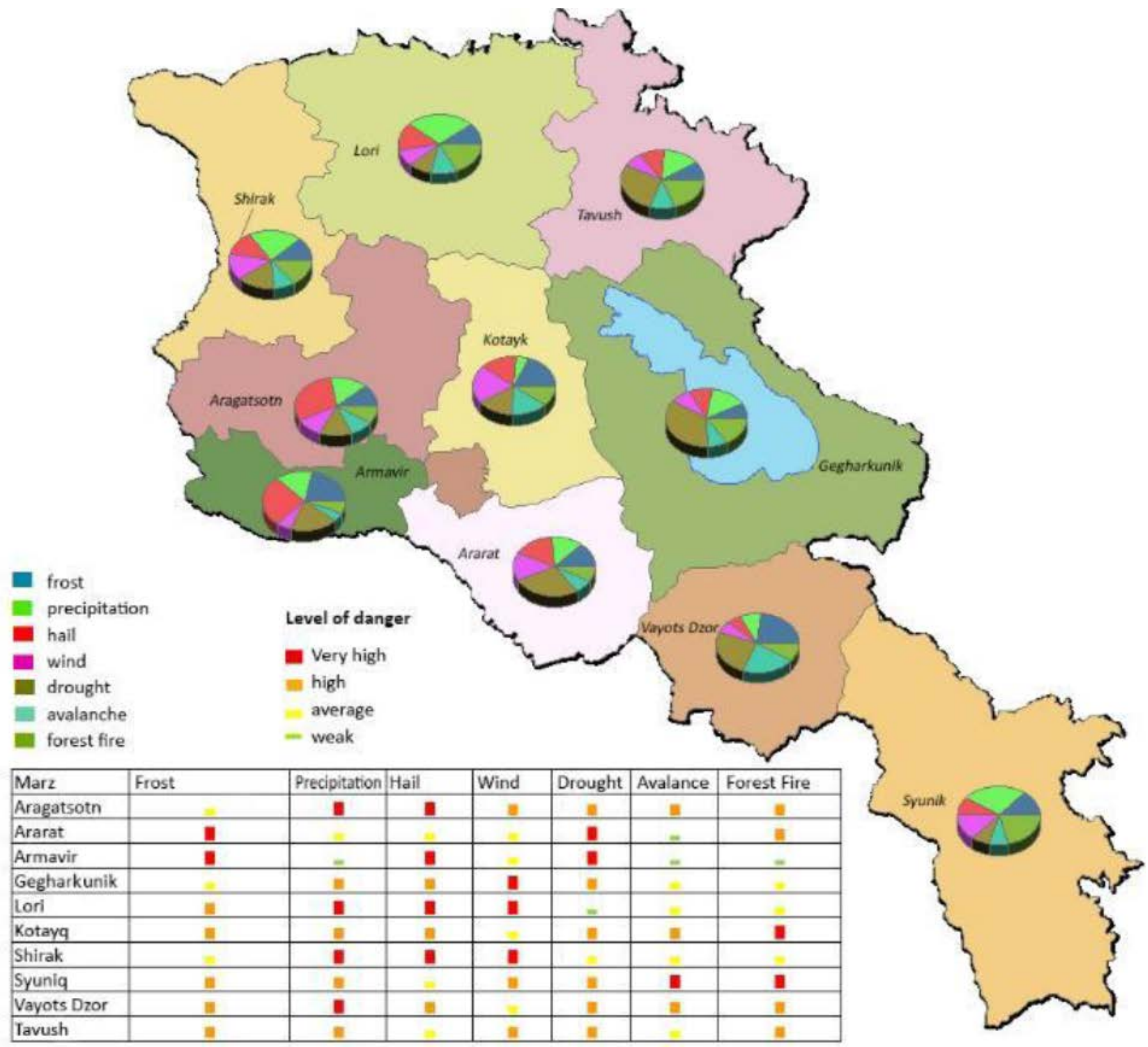

Figure 11 : Major causes of forest mortality in Armenia according to 4th national communication

Combat against natural disturbance is strongly linked with forest management.

It should be noted that Armenia already has an active policy of fighting against outbreaks due to pest and diseases. It proceeds every year to significant sanitary cuts. However, the lack of data on outbreak events limits the possibility to estimate the extent of the phenomenon and to know if the current practices of sanitary cuts are adequately dimensioned.

Unitary mitigation impact

Not estimated.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.3 Agriculture actions

4.3.1 Plantation of perennial crops (AGR1)

Principle

Planting orchards increases carbon sequestration in soil and biomass (and potentially reduces greenhouse gas emissions compared to cultivated land).

Orchards may generate a carbon sink because of the processes of carbon storage in wood: photosynthesis captures atmospheric CO_2 and stores it in the orchard's woody biomass over the life of the orchard. It is like a forest plantation but carbon stocks in forest are usually much higher than those observed with orchards.

At the end of the orchard's life, the trees are torn off and can be either:

- returned to the ground, allowing the use of carbon stored in biomass to increase carbon storage in the soil,
- energy production and thus contribute to the substitution of fossil fuels,
- used as building materials, for example, which extends carbon storage in biomass.

On average, the stock of aboveground and root biomass is higher in orchards than in annual crops and grasslands, so live biomass controls a well during the transition to orchard use.

Changing land use has a potential impact on soil carbon storage, particularly on organic carbon from the 0-30 cm horizon of soils. Indeed, the average ratio of biomass to soil varies according to the use. This variation will depend on the reference use of the plot and the grassing practices of the orchard.

Thus, in most situations, the regular deposit of litter (leaves, residues) on the orchard, root biomass associated with fine root renewal and permanent grassing lead to an increase in carbon storage in the soil compared to the baseline scenario.

National situation

In Armenia, currently, there is a promotion of intensive establishment of orchards for fruit and berries via provision of affordable targeted loans, which supports the development of horticulture, increase in the volumes of fruit and berry production, replacement of import and increase in the volume of export, as well as for the reduction of non-cultivated land areas – for example, areas of fruit and berry orchards have increased by 381 hectares as compared to 2014 (CBD, 2019)

But it can also be seen that the area of perennial plants has strongly decreased since 1990 and was more than divided by 2. This is a trend that exist in many other countries where mechanization and big farms have replaced farm family owners.

Lands	1990	1995	2000	2005	2010	2015	2016	2017
Total area	**1,384.0**	**1,391.4**	**1,391.4**	**1,391.4**	**2,100.9**	**2,045.7**	**2,045.5**	**2,043.8**
arable lands	492.0	483.5	494.3	494.3	448.5	446.7	446.4	446.0
perennial plants	83.6	74.1	63.8	63.8	32.9	34.4	34.7	34.8
grasslands	137.5	138.9	138.9	138.9	127.1	121.1	121.1	121.0
pastures	666.1	694.0	694.0	694.0	1,104.3	1,051.3	1,051.3	1,050.8
other lands	-	-	-	-	388.1	392.2	392.0	391.2

Source: SC (1991, 1995, 2001, 2011, 2018 Yearbooks)

Figure 12 : Agricultural lands reported under 4th national communication (RA, 2020 4th national com)

One of the limitations for the development of areas with perennial crops is the lack of water for irrigation. Different project aims at introducing drip irrigation in perennial plantations (orchards and vineyards), it is explicitly mentioned in the report on land degradation where projects exist on the the area of 2500 ha in two pilot regions (UNCCD, 2016).

Among the perennial crops, the vineyard has a particular status because it often concerns poor soils and consequently low biomass levels. In Armenia vineyards represent nearly around 40% of total perennial crops (NIR, 2017), the expected carbon gains by planting vineyards are rather limited. This limitation also concerns small red berry trees which are often very small and presents low level of biomass.

National land-use classification	RA Land Balance, ha	IPCC Guidelines Land Use categories, ha						
		3B1 Forestland	3B2 Cropland	3B3 Grassland	3B4 Wetland	3B5 Settlement	3B6 Other Land	Total, ha
1. Agricultural	**2,044,464.8**	**793**	**480,913**	**1,249,979**			**312,780**	**2,044,464.8**
1.1. arable land	445,564.5		445,565					445,564.5
1.2. perennial plants	35,348.3		35,348					35,348.3
1.2.1 orchards	21,052.6		21,053					21,052.6
1.2.2 grape vines	14,268.1		14,268					14,268.1
1.2.3 other perennial plants	27.5		28					27.5

Figure 13 : Perennial crops, orchards and grapes according to national inventory report (Table 4.3 in NIR, 2017)

Perennial crop plantation is part of the main directions of the national agricultural policy that have been defined in the "RA Strategy of Sustainable Agricultural Development for 2010-2020". One of the priorities of the crop production industry is the development of horticulture through establishment of orchards, preservation of cultivated and wild genetic resources of grapes, preservation and sustainable use of genetic resources of agricultural crops and their wild relatives (CBD, 2009).

The area of uncultivated lands has reduced, due to the implementation of state aid programs. The area of fruit and berry orchards has increased by 381 hectares as compared to 2014, making up 40 510 hectares in 2016. The increase in the prevalence of seed-bearing fruit trees is especially noticeable which amounted to 23,012 hectares in 2017 and 20,618 hectares in 2016 (CBD, 2009).

The expected result of projects is to increase the portion of the intensive orchards in the total orchard area up to 15-20% by 2022. As of 2016, the area of established intensive orchards on the territory of Armenia was 242 hectares, in 2017 it increased by 294 hectares, and by 2018 by about 190 hectares (CBD, 2020).

Unitary mitigation impact

To estimate carbon stocks from perennial crops in Mediterranean area it is relevant to consider the European life project named MEDINET (Canaveira et al, 2018).

The following tables make it possible to establish hypotheses on biomass stocks reached for different plant formations in Mediterranean ecosystems. These tables also indicate that the 20-year period is relevant to the duration of growth and maximum stock growth following plantation.

	Above Ground Biomass AGB (1)			Below Ground Biomass BGB			Total	Maturity cycle (2)
	tDM/ha	%C	$tC.ha^{-1}$	$tDM.ha^{-1}$	%C	$tC.ha^{-1}$	$tC.ha^{-1}$	years
Olive Trees	19.4	47%	**9.1**	5.8	45%	**2.6**	**11.7**	20
Vineyards	11.5	48%	**5.5**	9.7	45%	**4.4**	**9.9**	20
Fruit Trees	18.5	46%	**8.5**	12.8	45%	**5.8**	**14.3**	20
Shrublands	15.5	50%	**7.8**	22.0	50%	**11.0**	**18.8**	20

Notes: (1) "*Above Ground Biomass*" refers to biomass after pruning, which corresponds, in Mediterranean conditions, to the carbon stocks in the winter; (2) "*Maturity Cycle*" refers to the time needed for biomass to reach a stable level and not the normal replanting cycles of different crops.

Figure 14 : Proposed default carbon stocks at maturity (Medinet, 2018)

Table 30: Proposed Default Coefficients for Net Carbon Gains in Permanent Crops and Shrublands in the Mediterranean Region (unknown age)

	Biomass Carbon Accumulation Rate *conversions from other uses to permanent crop*							
	Conversion period		AGB		BGB		Total	
	years	U	$tC.ha^{-1}.y^{-1}$	U	$tC.ha^{-1}.y^{-1}$	U	$tC.ha^{-1}.y^{-1}$	U
Olive Trees	20	23%	0.46	27%	0.13	27%	**0.59**	**22%**
Vineyards	20	18%	0.28	26%	0.22	26%	**0.50**	**18%**
Fruit Trees	20	42%	0.43	46%	0.29	47%	**0.72**	**33%**
Shrublands	20	46%	0.39	49%	0.55	50%	**0.94**	**36%**

Notes: Assumes no-net change in biomass stocks after conversion period

Figure 15 : Proposed default coefficient for growth (Medinet, 2018)

The average impact of the action carried out on 1 ha allows the reduction of 43 tCO_2 over 20 years (2.14 tCO_2/ha/year for 20 years).

Application scale

The 4th national communication (RA, 2020b) shows a common picture among countries which is the strong decrease of perennial crops for decades. I

Table 1-9. Agricultural land, thousand ha

Lands	1990	1995	2000	2005	2010	2015	2016	2017
Total area	**1,384.0**	**1,391.4**	**1,391.4**	**1,391.4**	**2,100.9**	**2,045.7**	**2,045.5**	**2,043.8**
arable lands	492.0	483.5	494.3	494.3	448.5	446.7	446.4	446.0
perennial plants	83.6	74.1	63.8	63.8	32.9	34.4	34.7	34.8
grasslands	137.5	138.9	138.9	138.9	127.1	121.1	121.1	121.0
pastures	666.1	694.0	694.0	694.0	1,104.3	1,051.3	1,051.3	1,050.8
other lands	-	-	-	-	388.1	392.2	392.0	391.2

Source: SC (1991, 1995, 2001, 2011, 2018 Yearbooks)

Considering that the level could be reached again for 2050.

We consider that this action could be deployed on 2000 ha per year for 25 years for a cumulative surface area of 50 000 ha.

The probability to reach such level of plantation is medium because it is encouraged by national policies and represent an area that has already exist in the past in Armenia (1990s).

Global mitigation impact

The overall impact of this action would reduce emissions of 1689 $ktCO_2$ for the entire period 2018-2050.

4.3.2 Development of agroforestry and hedgerows (AGR2)

Principle

The greenhouse gas balance of agricultural land can be improved by increasing storage in biomass or carbon soil organically. This storage can be increased by the development of woody biomass and by greater soil restitution of organic matter. The action aims to plant trees in agricultural plots in large arable or grass crops (agroforestry), or their periphery (hedges). It is like a forest plantation but carbon stocks in forest are usually much higher than those observed with agroforestry systems.

"Agroforestry" is a generic term for a method of exploitation of agricultural land that combines trees and crops or pastures. Once common, these practices were phased out during the 20th century in developed countries, mainly for reasons related to the intensification and mechanization of agriculture. Recently, a new "modern" agroforestry, combining tree alignments and mechanized infill culture.

National situation

In available literature rather low information exist on hedgerows for Armenia, but it is of course a way to increase biomass on lands but also in soils.

According to report on land degradation one of the main objectives to stop cropland degradation and apply agroecology (conservation + modern "organic" technology). Currently, about 2/3 of all agricultural lands are at different stages of degradation. The reasons are clear: first of all because the small allotments owners do not apply modern methods of cultivation, crop rotation is not very often, incorrectly applied fertilizers, irrational use of pesticides, lack of irrigation water, the abundant use of artesian water, causing secondary salinization of soil, among other causes. In the next 10 years, a pilot project will be undertaken to promote among local people their conversion to "organic agriculture" technology, in particular to the widespread use of manure, compost and others as fertilizer. The country has already implemented projects to build reservoirs to collect and use rainfall water as a source of water for irrigation during dry season. Additionally, wide technical support will be undertaken on the rational use of land resources. It is expected to expand the rate of agricultural areas under permanent crops (UNCCD 2016).

it is necessary to extend the action to raise awareness of both the impact of land degradation and desertification and the goals and objectives of the LDN program, as well as to raise public awareness about modern methods of agriculture and forestry ("organic" agriculture, drip irrigation, crop rotation, zero tillage, soil amendment, keyline design, hedgerow growing, agro-forestry, transformation of mono-silviculture in full standing forest ecosystems, etc.) (UNCCD 2016).

Unitary mitigation impact

Carbon stocks in the biomass hedgerows for farmland is highly dependent on the type of hedgerows and the density of hedgerows. These are landscape elements that are not well known in Armenia. In landscapes with many hedges, one will find classically between 60 and 100 meters of hedge per agricultural hectare. With a value of 80 meters per hectare and an average value of 0.20 m^3 of wood per meter of hedge, there is an additional stock of about 5 tC/ha of agricultural area. This value remains rather small and it is rather similar for agroforestry systems.

Hedgerows are also good practice to increase carbon soil on croplands.

the average impact of the action carried out on 1 ha allows the reduction of 15 tCO_2 over 20 years (0.76 tCO_2/ha/year for 20 years).

Application scale

There is no clear reference on the current state of agroforestry and hedgerows in current agricultural landscapes of Armenia. And there is no clear plan on such dynamics which can be seen as contrary to modernisation of agriculture.

We consider that this action could be deployed on 5 000 ha per year for 30 years for a cumulative surface area of 150 000 ha.

The probability for such mitigation action remains low, and the knowledge on current situation is also very low.

Global mitigation impact

The overall impact of this action would reduce emissions of 1 163 $ktCO_2$ for the entire period 2018-2050.

4.3.3 Non cultivation of organic soils (AGR3)

Principle

The Cultivation of organic soil may lead to large emissions of CO2 (and possibly to CH4). These emissions are related to lowering water levels because of drainage activities. This drainage exposes soil carbon to degradation. These organic soils may have been converted to agricultural land in the past by drainage, but these emissions are maintained for a very long time, carbon stocks of organic soils can be quite large.

National situation

In Armenia, according to the national inventory report (NIR, 2017), there are areas of exploited peatlands. There are therefore areas with organic soils but there is no information on the possible use of this land for agricultural production. As these lands are not very fertile land for cultivation and Armenia with a lot of abandoned agricultural land, it is reasonable to assume that these lands with organic soils are not dedicated to agriculture and that it is therefore not possible to reduce their emissions.

Unitary mitigation impact

Not estimated

Application scale

Inexistant

Global mitigation impact

Not estimated

4.3.4 Limitation of exports of biomass from crops (AGR4)

Principle

Soil organic matter results from the balance between incoming carbon (crop residues, organic amendments) and degradation (dependent on pedoclimatic conditions). To maintain or increase a carbon stock, biomass restitutions can be increased on the ground and, above all, practices can be limited to preventing these ground-based returns. This is particularly the case for straw exports, the carbon of which will potentially be returned to agricultural land if this straw is used in livestock and the manure produced is applied.

The main practice to limit if the goal is to preserve carbon from the soil is the burning of agricultural residues. The burning of straws, for example, is practiced in many countries to facilitate tillage for subsequent crops and to manage weed pressure. Alternatives to burning are dependent on the level of mechanization of agriculture and possibly the availability of herbicides.

National situation

In Armenia's national inventory report there is an estimate of biomass burning on cropland estimated around 18 kha per year. This can be considered as residue burning after cultivation.

Unitary mitigation impact

The level of return of an organic matter to the soil is difficult to integrate directly into a calculation. Otherwise, the 2006 IPCC guidelines apply, this can be estimated by qualitatively assessing these refunds in several ways:

- Low inputs
- Medium inputs
- High inputs (without manure)

It can be assumed that stopping biomass burning can change a crop from the category of low inputs to medium inputs. This can lead to an increase of 5% of soil organic carbon (IPCC 2006 table 5.5, dry climate).

The average impact of the action carried out on 1 ha allows the reduction of 5 tCO_2 over 20 years (0.23 tCO_2/ha/year for 20 years).

Moreover, the burning of residues is responsible for 0.28 tCO_{2eqv} /ha burnt (CH4 + N2O).

Application scale

When crop residues are not burned, crop residues return to the ground by grinding, buried, grazed or left decomposed on the surface.

There is potential for improvement to increase these inputs. Obviously, this practice is linked to other methods of improving the carbon stocks of soils, in the case of a scenario on agricultural land it is necessary not to double count the possible increases in carbon stocks on cultivated land.

We consider that this action could be deployed on 18 000 ha (all are subject to biomass burning).

Global mitigation impact

The overall impact of this action would reduce emissions of 82 tCO_2 for the entire period, in relation with carbon soil increase.

And an additional benefit would be the mitigation of CH_4 and N_2O emission from burning estimated at 5 kt CO_{2eqv} /year in the baseline. It could be counted as 150 ktCO2e for the entire period 2018-2050

4.3.5 Development of non-till farming techniques (AGR5)

Principle

The greenhouse gas balance of agricultural land can be improved by increasing the storage of carbon in the soil under the form of organic matter. This storage can be increased by cropping practices that delay the mineralization of organic matter and thus increase their storage time in the soil. The abandonment of ploughing is deemed to have this effect.

Because ploughing is defined by the fact that it achieves a reversal of the soil, the "Simplified Cultural Techniques" (TCS) encompass all practices that do not occur such a reversal, but which are very diverse, from a more or less superficial work of the soil to direct sowing and will have different impacts.

It is important to note that this effect is controversial because stopping ploughing can lead to a redistribution of carbon in soils without a real increase in total stock. This effect depends on the climatic conditions. It is also important to note that this action is likely to increase N_2O emissions, which depend on soil-specific conditions.

National situation

No-tillage practices are quickly cited as good practices in the land degradation report (UNCCD, 2016), but without having quantified evidence of current practices.

Unitary mitigation impact

The impact of no-tillage and simplified techniques is quite significant on the carbon of agricultural soils if we use the 2006 guidelines of the Giec, it is the main option of action on the carbon of agricultural.

The transfer of an area from full tillage to reduced tillage can lead to an increase of 4% of soil organic carbon (IPCC 2006, Table 5.5, moist climate).

The average impact of the action carried out on 1 ha allows the reduction of 4 tCO_2 over 20 years (0.18 tCO_2/ha/year for 20 years).

Application scale

By default we consider a conventional type of tillage and therefore with mouldboard ploughing on all arable land and therefore a significant potential for improvement

We consider that this action could be deployed on many cases, for example 5000 ha per year for 20 years for a cumulative surface area of 100 000 ha with reduced tillage.

The probability to manage such action is low considering the main objectives in terms of mecanisation of agriculture.

Global mitigation impact

The overall impact of this action would reduce emissions of 322 ktCO2 for the entire period 2018-2050.

4.3.6 **Increase biomass productivity of crops (AGR6)**

Principle

The greenhouse gas balance of agricultural land can be improved by increasing carbon storage in soils with return of larger amounts of organic matter to the soil. It can be done through productivity increase of crops. The main ways to increase plant productivity are seed quality and varietal choices, fertilization, irrigation, and pest management.

It is important to note that increased production may involve increased fertilization or irrigation that may encourage emissions of other greenhouse gases than CO_2.

National situation

For the last 15 years the agriculture in the Republic is in the phase of extensive ploughing; there are almost no scientifically developed agro-activities. For the last decade, the use of mineral fertilizers has been reduced more than 10 times, and that of organic fertilizers - about 18 times. At the same time, according to the data from the National Statistical Service of the Republic of Armenia, the import of pesticides rises year by year, which results in additional soil and water contamination (CBD, 2009)

Increasing the efficiency of land use is one of the most important issues in the agriculture sector. It has been stipulated in the Sustainable Agriculture Development Strategy of RA (2015-2025). The strategy envisages to include at least 10 thousand hectares of unused arable land in crop rotation per annum. As of 2017, the area of unused arable land in the country comprises over 200,000 hectares. The Government is developing a relevant legislative package aimed at the inclusion of unused arable land into crop rotation. To this end, it is envisaged to put an instrument in place to oblige the landowners to cultivate the land under their possession or to lease it, if own cultivation is not practicable (RA, 2020b).

Unitary mitigation impact

Productivity of biomass is partially linked with level biomass restitution. The main objective for cultivators is to maximize the yields and sometimes minimize the residues. But good productivity is often positively correlated to large amount of crop residues.

This action is linked to that on the management of residues and participates similarly to the storage of carbon in the soil. The more biomass crops produce, the more likely they are to generate residues and the greater the return of organic matter to the soil.

As with the return of residues to the ground, the IPCC proposes a qualitative method to integrate the level of inputs (low, medium, high).

Looking as the yields for wheat in Armenia (FAOSTAT, 2021), the results gives between 2 and 3.5 t of grains per ha. In most developed countries, the yields are between 6 and 7 tons per ha. The potential increase in productivity is important for Armenia, but this may lead to increased use of fertilizer, whose greenhouse gas emissions are also known.

It can be assumed that boosting yields (with additional fertilization especially) can change a crop from the category of low inputs to medium inputs. This can lead to an increase of 5% of soil organic carbon (IPCC 2006 table 5.5, dry climate).

The average impact of the action carried out on 1 ha allows the reduction of 5 tCO_2 over 20 years (0.23 tCO_2/ha/year for 20 years).

At the same time, it can be assumed that emissions due to fertilization (in agriculture sector) will also be higher and the positive effect of increase inputs and organic carbon soil is not obvious.

Application scale

We consider that this action could be deployed on all cereal crops (wheat and barley) on 4000 ha per year for 25 years for a cumulative surface area of 100 000 ha.

The probability to reach such objective of biomass yield is medium, it recovers other agricultural policies.

Global mitigation impact

The overall impact of this action would reduce emissions of 358 ktCO_2 for the entire period 2018-2050.

4.3.7 Adjustment in the choice of cultivated species (AGR7)

Principle

The greenhouse gas balance of agricultural land can be improved by increasing carbon storage in soils with return of larger amounts of organic matter to the soil. It can be done prioritizing some crops known to produce a lot of biomass residues (rapeseed, maize and cereals can produce a lot of residues, carrots and potatoes produce very small amounts of residues).

This action can also include the promotion of temporary grassland in crop rotations and the increase of the frequency of temporary grassland in these rotations.

National situation

Most of croplands are dedicated to wheat, barley and potatoes in Armenia (FAOSTAT, 2021). Cereals generate a lot of residues but potatoes give very low level of residue restitutions.

Unitary mitigation impact

The increase of inputs can be obtained by higher productivity and better management of residues but also by changing the rotation crops. The different crops have different capacities in terms of carbon restitution to soil and the choice of these crops can vantage or penalize carbon accumulation in soil.

It is necessary to make complex modelling to analyse the effect of the specific crop rotations in Armenia, but simplified information can be used to estimate the capacity of carbon sequestration for crops in Armenia.

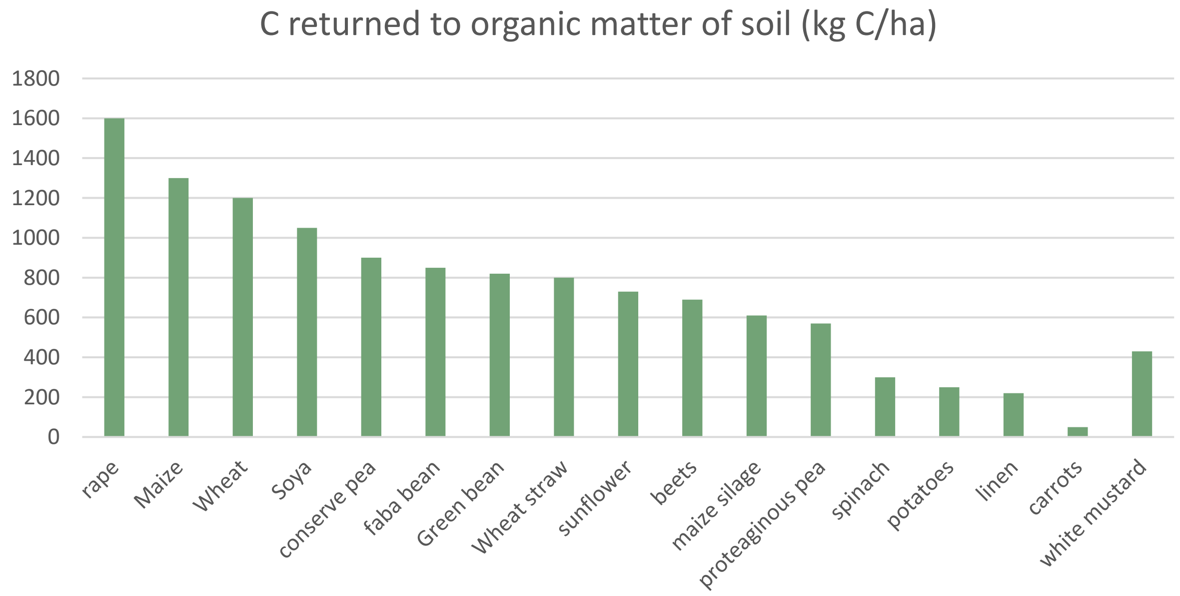

Figure 16 : Carbon returned to soil by several crops (SIMEOS-AMG model)

Changing mix of crop production is a too political issue that cannot be recommended as a mitigation actions. For example, potatoes are directly linked with food security.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.3.8 Introduction of more intermediate crops, intercrops, grassed strips (AGR8)

Principle

The greenhouse gas balance of agricultural land can be improved by increasing carbon storage in soils with return of larger amounts of organic matter to the soil. It can be done through intermediate crops on large-scale land or herbaceous cutlery in orchards, vineyards or along streams.

Three main practices are identified:

- intermediate crops sown between two commercial crops for large-crop systems (temporary covers of 3 to 6 months depending on the duration of the interculture);
- intercropping in orchards and vineyards (temporary or perennial herbaceous cover between rows of trees or vines);
- grassed strips at the edge of streams or on the periphery of cultivated plots (perennial covered).

Intermediate crops is the major mitigation action for crop cultivation in many countries, it has a lot of co-benefits and is their effect is known will good confidence.

National situation

No information was found considering that the practice of intermediate crops during winter is developed in Armenia. It is mentioned among the good practices contributing to the restoration of the structure (Green manuring, increasing the proportion of grass in the crop rotation of the wedge, the use of artificial structure-builders and so on) (Ghazaryan et Kroyan, 2016)).

Unitary mitigation impact

It can be assumed that planting crop cover during winter can change a crop from the category of middle inputs to high inputs. This can lead to an increase of 4% of soil organic carbon (IPCC 2006 table 5.5).

The average impact of the action carried out on 1 ha allows the reduction of 4 tCO_2 over 20 years (0.18 tCO2/ha/year for 20 years).

Application scale

It can be assumed that planting crop cover during winter can be done for example before potatoes, beets and maize.

We consider that this action could be deployed on 3 000 ha per year for 10 years for a cumulative surface area of 30 000 ha.

This action is possible without demanding too many changes, it is one of the best agricultural practices to promote.

Global mitigation impact

The overall impact of this action would reduce emissions of 109 $ktCO_2$ for the entire period 2018-2050.

4.3.9 **Increase of manure application (AGR9)**

Principle

The climate impact of agricultural land can be improved by increasing carbon storage in soils with addition of large amounts of organic matter to the soil. The main organic matter used in agriculture is animal manure.

In general, animal manure is used in agriculture and therefore already valued, so there is little possibility of increasing the amounts brought to agricultural soils, but the systems can be modified to favour the modification of arable land.

National situation

In the next 10 years, a pilot project will be undertaken to promote among local people their conversion to "organic agriculture" technology, to the widespread use of manure, compost and others as fertilizer (Unccd, 2016)

Addressing the decline in soil fertility under annual crop through extensive use of organic nutrients (manure, compost, manure processed by red Californian worm). The area is 7 000 ha. The project involves the purchase and delivery of organic fertilizers from other regions of Armenia, where is a well-developed animal husbandry, and manure accumulates in large quantities. (Unccd, 2016)

Unitary mitigation impact

It can be assumed that increasing fertilization with manure can change a crop from the category of middle inputs to high inputs with manure. This can lead to an increase of 37% of soil organic carbon (IPCC 2006 table 5.5).

The average impact of the action carried out on 1 ha allows the reduction of 34 tCO_2 over 20 years (1.68 tCO2/ha/year for 20 years).

Yet it can also be assumed that N2O emissions increase which limit the confidence in the positive mitigation of this action.

Application scale

Increasing manure is not easy because it is directly linked with livestock and already use (usually) for organic fertilisation. Nevertheless, it is mentioned in this project that there is a 10 year project converting 7000 ha to organic agriculture.

We consider that this action could be deployed on 1000 ha per year for 10 years for a cumulative surface area of 10 000 ha.

The knowledge on manure management is low, but the probability to manage the improvement of manure on a moderate scale is rather high.

Global mitigation impact

The overall impact of this action would reduce emissions of 336 ktCO2 for the entire period 2018-2050.

4.3.10 Optimization of water management (AGR10)

Principle

The greenhouse gas balance of agricultural land can be improved by increasing carbon storage in soils with addition of large amounts of organic matter to the soil. Optimization of water management may lead to higher productivity of fields and indirectly to higher return of organic matter to soil.

This modality is not raised by the IPCC guidelines but proposed by the FAO in its former version of the Ex-ACT tool. But it is not included anymore in latest versions.

National situation

In the report for the Convention on biodiversity (RA, 2009), irrigated areas are mentioned.

Water management is clearly an issue for Armenia and many projects are raised to manage the challenge of irrigation in Armenia.

The Government has developed a program for subsidizing interest rates on loans for the installation of drip irrigation systems, whereby the interest rate on such loans is less than 2%. The Program aims to promote the introduction of advanced irrigation methods for perennial plants – fruit orchards and vineyards, high value crops. Within the framework of the Program, it is envisaged to install drip irrigation systems over 1.6-1.7 thousand hectares of land annually in 2018-2022. (RA, 2020b)

Table 12 : Irrigated areas in Armenia

		Total	Including irrigated
1	Area of the Republic of Armenia	2974.26	208.97
1.1	Available land of the Republic of Armenia by end use		
a)	farmland	2121.21	155.85
	including arable land	450.36	123.48
	perennial plantations	31.57	30.88
	hayfields	127.36	1.50
	grasslands	1117.14	-
	other lands	394.78	-
b)	residential lands	151.24	52.69
c)	industrial, mining and other production lands	29.20	-
d)	lands of energy, communication, transport and municipal infrastructures	12.20	-
e)	specially protected nature areas	229.72	-
f)	special-purpose lands	31.69	-
g)	forest lands	369.78	0.43
h)	water lands (excluding Lake Sevan and other specially protected water areas)	28.59	
i)	reserve lands	0.63	-

Source: National Statistical Service of the Republic of Armenia

The project aimed at the introduction of drip irrigation systems contributes to the replacement of traditional irrigation methods that are inefficient and cause water erosion with water-saving and environmentally friendly technology. The traditional canal irrigation on steep slopes leads to the accumulation of water outside the cultivated area and the occurrence of swamping, which, in turn, endangers the natural habitat of plants. Irrigation on steep slopes with drip irrigation prevents the occurrence of swamping and preserves plant habitats. According to data from the regional administrations, drip irrigation systems are currently being used on 1740 hectares. (RA, 2019)

Unitary mitigation impact

It can be seen as a way to increase productivity turning a crop from dry situation to moist situation. This can lead to an increase of 6% of soil organic carbon (IPCC 2006 table 5.5) with the assumption that inputs are high.

The average impact of the action carried out on 1 ha allows the reduction of 6 tCO2 over 20 years (0.32 tCO2/ha/year for 20 years).

Application scale

We consider that this action could be deployed on 2000 ha per year for 4 years for a cumulative surface area of 8000 ha.

The probability to reach such objective is medium, it joins other policies.

Global mitigation impact

The overall impact of this action would reduce emissions of 51 ktCO_2 for the entire period 2018-2050.

4.3.11 **Optimization of grassland management (AGR11)**

Principle

Grassland surfaces 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 farming activities since these areas are most often maintained for grazing. Grasslands are most often carbon sinks.

However, the importance of this additional storage of prairie C, and more generally their greenhouse gas balance, depends on their type (permanent or temporary grass) and their mode of conduct (grazing and/or mowing, animal loading, fertilization level...).

The action aims to change the management of existing grasslands to improve their greenhouse gas balance; it does not envisage the creation of new grass surfaces (which would be a change in land use).

This optimization for an increase in carbon stocks is complex, it may correspond to a "de-intensification" of the most fertilized grasslands or a moderate intensification of unproductive permanent grasslands.

National situation

Many small owners became depend on sheep and cattle for their subsistence after the privatisation of the large collective farms. These animals usually forage in an unregulated manner in the meadows and grassland of state-owned forests. (Moreno-Sanchez 2005)

Stop overgrazing and improve grassland management in 100% of national territory in one of the objectives of the country. Armenia launched several pilot projects to inventory the practices of grazing throughout Armenia, recalculate grazing norms and adequate grazing regulations to different environmental conditions and different degrees of pastures degradation, through the development of management plans for use of grasslands for fodder conservation and grazing. (Unccd 2016)

To improve the condition and proper use of grasslands. Currently, more than half of all grassland ecosystems that are used as pastures and hayfields, are in various stages of degradation, caused both overgrazing and under grazing. Correct, science-based management of pastures and hayfields could improve the conditions of natural ecosystems, increase the stock of carbon sequestrated, will enable efficient use of plant resources, will improve the opportunities for the development of animal breeding. At the same time to improve the condition of pastures, besides choosing the right pasture capacity, it is necessary to implement modern measures to improve greatly degraded overgrazed pastures, implementation of rotational grazing system. It is necessary to organize a proper system for watering animals in the grazing field, to avoid overloading pastures with too many animals and trampling ecosystems and compacting soil in water reservoirs vicinities. In some cases, when the degradation has reached the extreme steps, it is possible to transfer such pastures to land intended for afforestation. (CBD 2009)

In Armenia livestock breeding is one of the most important branches of agriculture due to its natural conditions and the existence of high mountainous fodder-producing areas (pastures, grasslands) that have great importance. They are also of great value in terms of biodiversity. Approximately 59% of agricultural land registered in the Republic is composed of natural fodder-producing areas that occupy about 1 244 000 hectares. During the last 20-25 years, the total number of farm animals has dropped considerably, but degradation processes have been significantly enhanced because of irregular use of fodder-producing areas. Due to the lack of improvement measures of vegetation cover degradation processes have significantly increased. Pasture degradation is a widespread phenomenon in Armenia that leads to disturbance of the balance of nature and reduction in land productivity. Biological productivity has decreased 1.5-2 times as compared to 1950s, which is a direct threat to sustainable agricultural development and, consequently, food self-sufficiency. Hence, given the fact that Armenia is a land-poor country ensuring food self-sufficiency becomes a strategic issue. (CBD 2009).

The degradation of lands and natural pastures will intensify. By 2030, the total area of pastures and the level of crop yield thereof will be reduced by 4-10%, while, in case of more valuable pastures located in sub-alpine and alpine zones, the yield will decrease by 19-22%. It is also forecast that the level of crop yields in grasslands will decrease by 7-10%, which, in turn, will result in reduction of fodder production volumes (RA, 2020b).

Unitary mitigation impact

According to the IPCC, there are 4 categories of grassland (severely degrade, moderately degraded, nominally managed, improved grassland)

All the actions mentioned in the national policy could lead to the transfer from the class moderately degraded (high intensity grazing) to nominally managed. This can lead to an increase of 10% of soil organic carbon (IPCC 2006 table 6.2).

The average impact of the action carried out on 1 ha allows the reduction of 10 tCO2 over 20 years (0.51 tCO2/ha/year for 20 years).

Application scale

We consider that this action could be deployed on 20 000 ha per year for 25 years for a cumulative surface area of 500 000 ha to reach 1/3 of total grassland (currently, half of grassland would be degraded, unccd 2016)

It is very challenging to act on degraded grasslands, but with lower pressure from livestock it could be realistic. The probability to see such action is considered as medium.

Global mitigation impact

The overall impact of this action would reduce emissions of 4 063 ktCO_2 for the entire period 2018-2050.

4.3.12 Restoration of degraded soils (acidified, eroded, salty soils) (AGR12)

Principle

Degraded land are most often lands with low stocks of carbon in soils. It is logical because organic matter is strongly linked with biomass productivity of lands. The restoration of degraded land is dependent on the type of degradation.

- For acidity, it can be done by liming of course (even if liming is a source of CO_2).
- For erosion it is a big challenge which usually implies the plantation of specific species capable to grow in poor conditions and slowly, soil can be restored.
- For salty soils, irrigation is necessary. This is a bit of a paradox because salty soils are also often the result of past irrigation.

National situation

Water erosion at various stages listed on nearly half of all forestland in all forest regions of Armenia (186200 ha). Likewise, it is registered in almost half of all cropland in all regions of the country (220000 ha), except orchards and vineyards.

LDN national target: By the year 2040, the carbon stock lost between 2000 and 2010 will be recover and increase by 2,8% in relation to present (Unccd 2016).

This action treats of areas which are no more grasslands because of degradations dues for example to mining activities. Restoration of degraded grassland which are still grasslands are covered in action on optimization of grassland management.

Unitary mitigation impact

Not estimated.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.3.13 Spreading of "inert" carbon (e.g. biochars)(AGR13)

Principle

Biochar is an amendment of the soil derived from biomass pyrolysis. This amendment is considered as a technique for soil carbon storage because biochar is assumed to degrade very slowly in soils. This technique is controversial as the actual sustainability of carbon from biochar is dependent on pedoclimates and the effects on soil biology are poorly understood. But the IPCC 2019 refinement guidelines allow the estimate of effects due to biochar application.

National situation

Not mentioned.

Unitary mitigation impact

Not estimated.

Application scale

Not estimated.

Global mitigation impact

Not estimated.

4.4 Other actions

4.4.1 Limitation of peat extraction (OTH1)

Principle

Peat mines are directly sources of CO_2 on site and have carbon losses due to peat extraction (which returns to atmosphere once consumed for agriculture or energy production.

National situation

Peat occurs on 1.5% of the territory of Armenia. Peatlands are of lowland origin and formed from sedges with 10-40% addition of reeds. The area of peat mines is 489 ha, and more than 1,065 ha is occupied by peat occurrences. Peat stocks estimated 1,005,375 tones. High uncertainty and even controversy exists in available data on the volume of extracted peat. Armenian peat is used as fertilizer, fuel, in balneology and is subject of export. The official data on peat extractions varies significantly by years. In 2017, the volume of peat extracted was 9905.7 tonnes.

Unitary mitigation impact

The mitigation level directly linked with emission per ha of peat mines (4 tCO_2/ha/year) and the amount of peat extracted (1.65 tCO_2/t peat extracted).

Some emissions of N_2O are also to be considered (0.5 tCO_2eqv/ha/year).

Application scale

We consider that this action could be deployed on the global extraction area which is 489 ha in 2017.

But it seems rather strange to stop an economic activity, the probability of this action is low.

Global mitigation impact

The overall impact of this action would reduce emissions of 230 $ktCO_{2eqv}$ for the entire period 2018-2050.

5. Mitigation potential for Armenia

All proposed actions are presented in the following table with the possible effects and the area concerned. All these actions are not independently treated because there is just one territory, and it is not possible to cover all grassland with forest and optimize grasslands at the same time.

Table 13: List of mitigation actions for LULUCF

N°	Long name	Mitigation 2018-2050 (ktCO2eqv)	Area 2018-2050 (ha)	Mitigation 2018-2050 (tCO2eqv /ha)
LUC1	prevention of soil sealing on cropland	-1	30	32
LUC2	prevention of grassland conversion to cropland	-366	20 000	18
LUC3_C	prevention of deforestation to implement crops	-471	2 000	235
LUC3_G	prevention of deforestation to implement crops	-1 534	7 000	219
FOR1	afforestation on crops	-43 579	250 000	174
FOR2	restoration of degraded forests	-6 761	200 000	34
FOR3	optimization of forest management practices	-742	30 000	25
FOR4	sawnwood wood harvest regulation	0	0	0
FOR5	fuelwood harvest regulation	-663	100 000	7
FOR6	increase amount and lifespan of harvested wood products	0	0	0
FOR7	limitation of wood losses during harvesting	0	0	0
FOR8	prevention of forest fire events	-105	3 000	35
FOR9	prevention of other natural disturbances (windfalls, snow breaks)	0	0	0
AGR1	plantation of perennial crops	-1 689	50 000	34
AGR2	development of agroforestry and hedgerows	-1 163	150 000	8
AGR3	non cultivation of organic soils	0	0	0
AGR4	limitation of exports of biomass from crops	-233	18 000	13
AGR5	development of non-till farming techniques	-322	100 000	3
AGR6	increase biomass productivity of crops	-358	100 000	4
AGR7	adjustment in the choice of cultivated species	0	0	0
AGR8	introduction of more intermediate crops, intercrops, grassed strips	-109	30 000	4
AGR9	increase of manure application	-336	10 000	34
AGR10	optimization of water management	-51	8 000	6
AGR11	optimization of grassland management	-4 063	500 000	8
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
OTH1	Limitation of peat extraction	-270	489	552

There are two major principles when it comes to LULUCF reduction techniques:

- The territory is a limited (finite) area.
- Mitigation actions have a limited duration and are reversible.

The following graph shows that land subject to action is compatible with the territory by working as if each action were a project with a parcel of the land. This avoids significant inconsistencies.

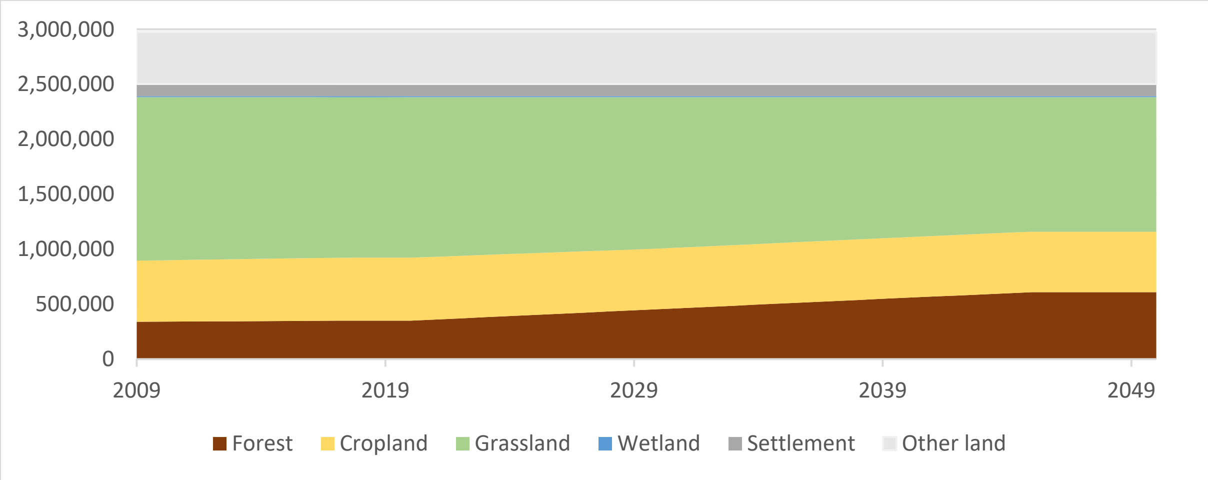

Figure 17 : Areas per category of land use (ha)

Similarly, when the area covered by actions is shown, it fits correctly into the territory.

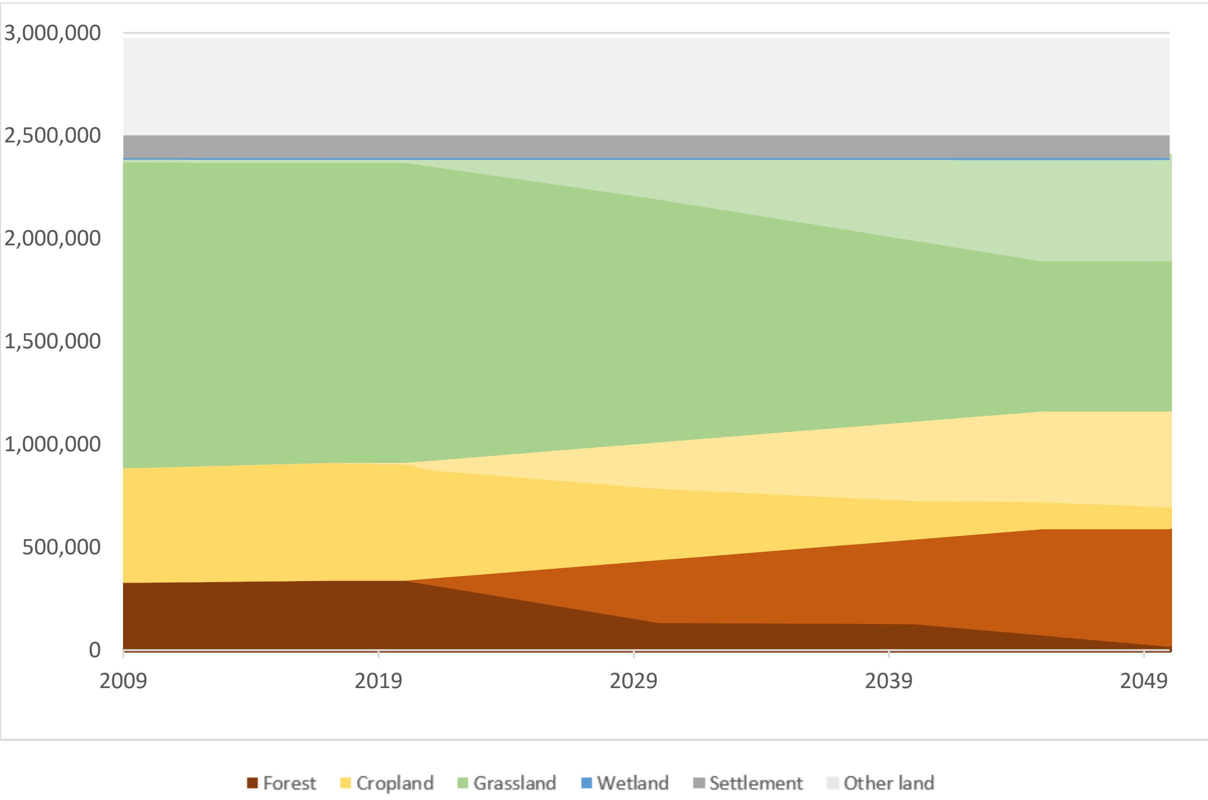

Figure 18 : Areas per category of land use (ha) with area concerned by actions (lighter color)

With application with this very ambitious set of mitigation action, the LULUCF inventory present the following trend for coming years.

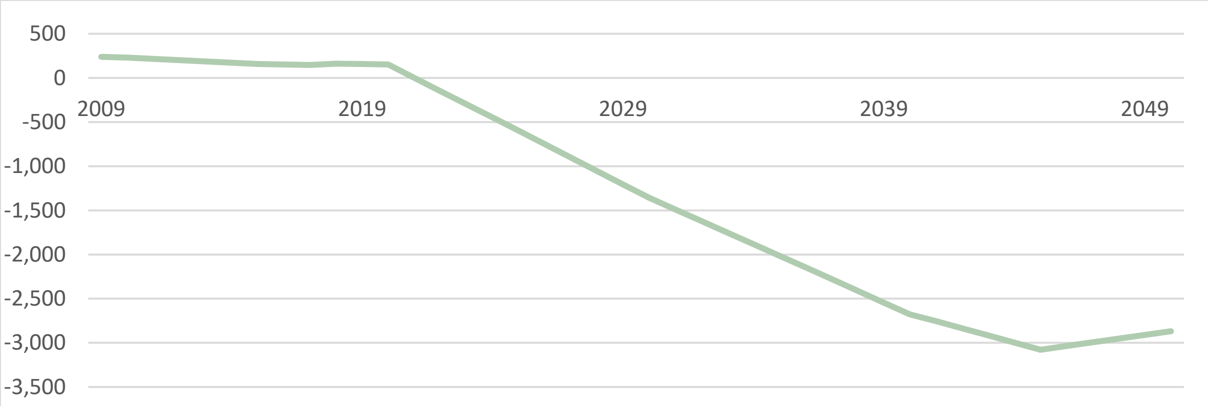

Figure 19 : Emissions and removals for LULUCF sector with application of actions

On this diagram the limit of time that exist for many mitigation actions can be seen. There is a peak of effects and then the results decrease. This trend is of course very linked with afforestation because modeling was made with high level of afforestation. But other actions can be important although they cannot concern such large areas.

The two following graphs shows the different mitigation impact of all actions. The first graph shows the effect of each action *per hectare* (unitary impact), and the second graphs show the overall impact of each actions once implemented on the available area. Therefore, one action that has a great potential per ha (such as the action OTH1 – limitation of peat extraction) actually can be implemented over a small area so its effect remains limited on the second graph.

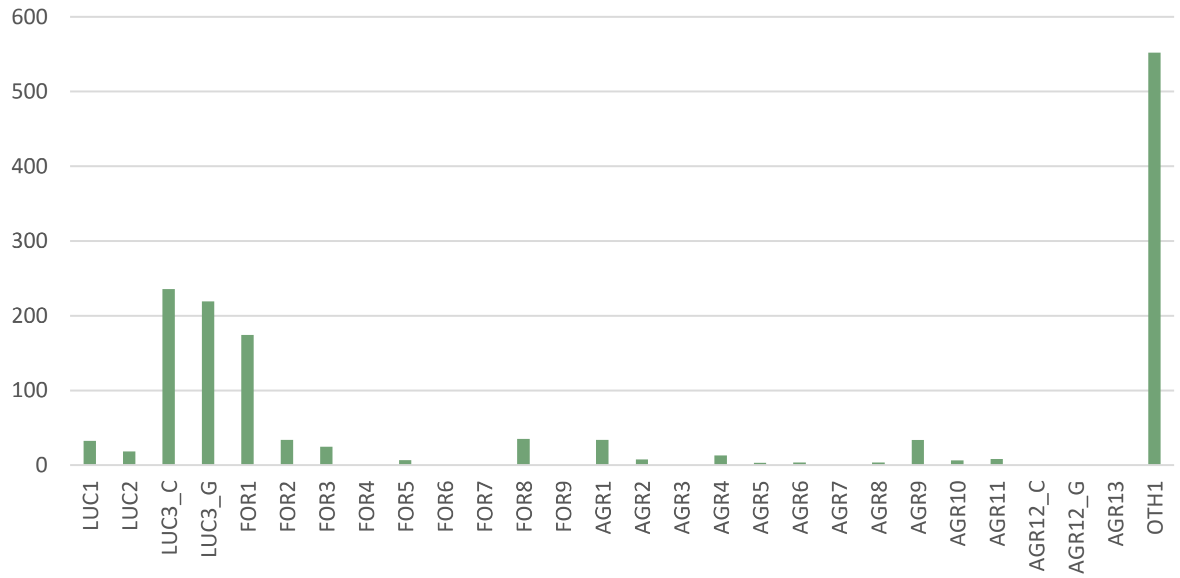

Figure 20 : Reduction reached with mitigation action (tCO2eqv/ha) for 2018-2050

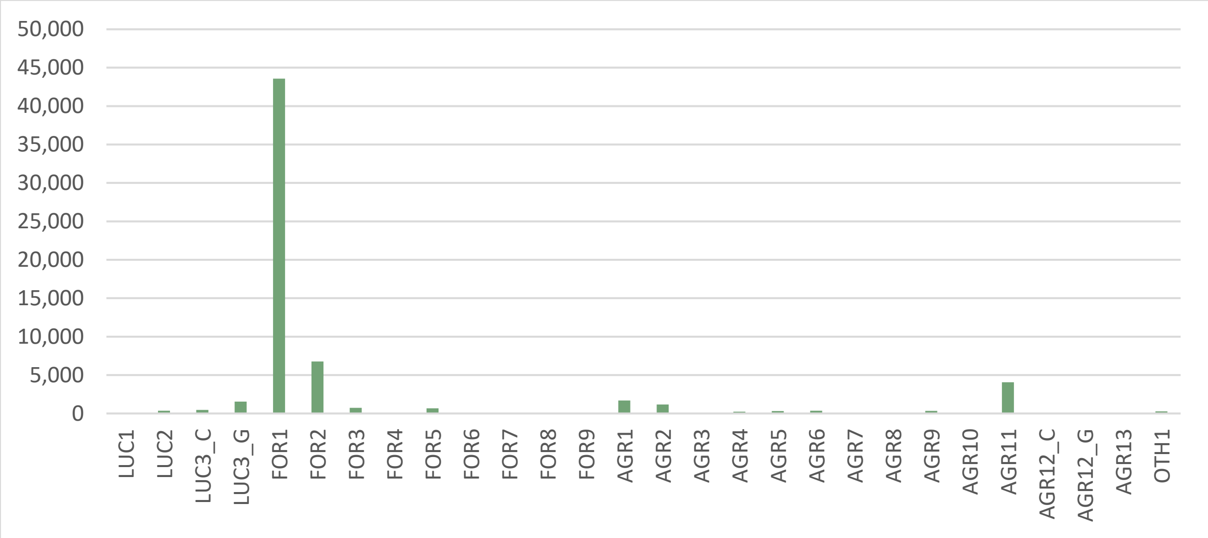

Figure 21 : Reduction reached with mitigation actions (ktCO2eqv) for period 2018-2050

The following diagram shows the contribution of each action over time. The impact of actions is a bit hidden by the effect of action FOR1 (afforestation) which is very important considering the large areas that are expected for this action.

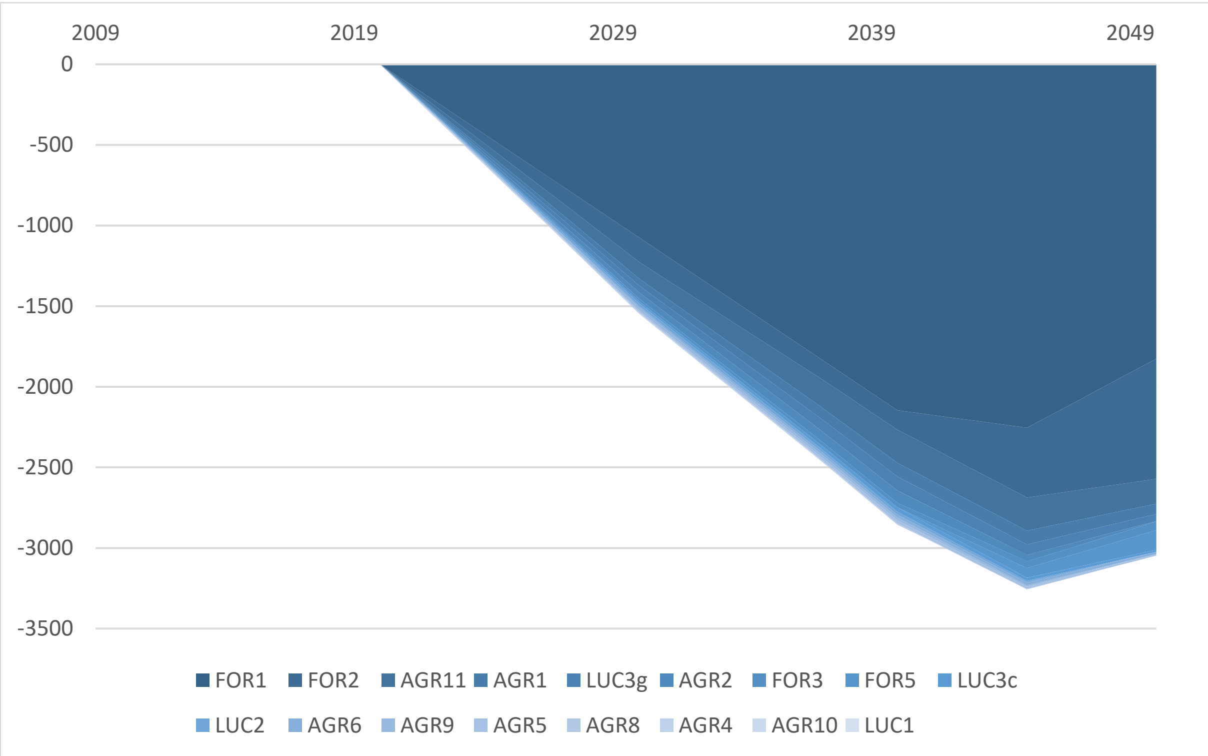

Figure 22 : Cumulative effect from mitigation actions (kt CO2eqv) (listed by order of magnitude)

Another indicator that has been followed when proposing application scale is the provision of woodfuel. Harvesting rates were too high in last two decades, but it is important to keep the possibility of using biomass resources for populations. With high rates of plantation, a high level of wood provision could be maintained even if it remains very difficult to correctly estimate biomass productivity of lands.

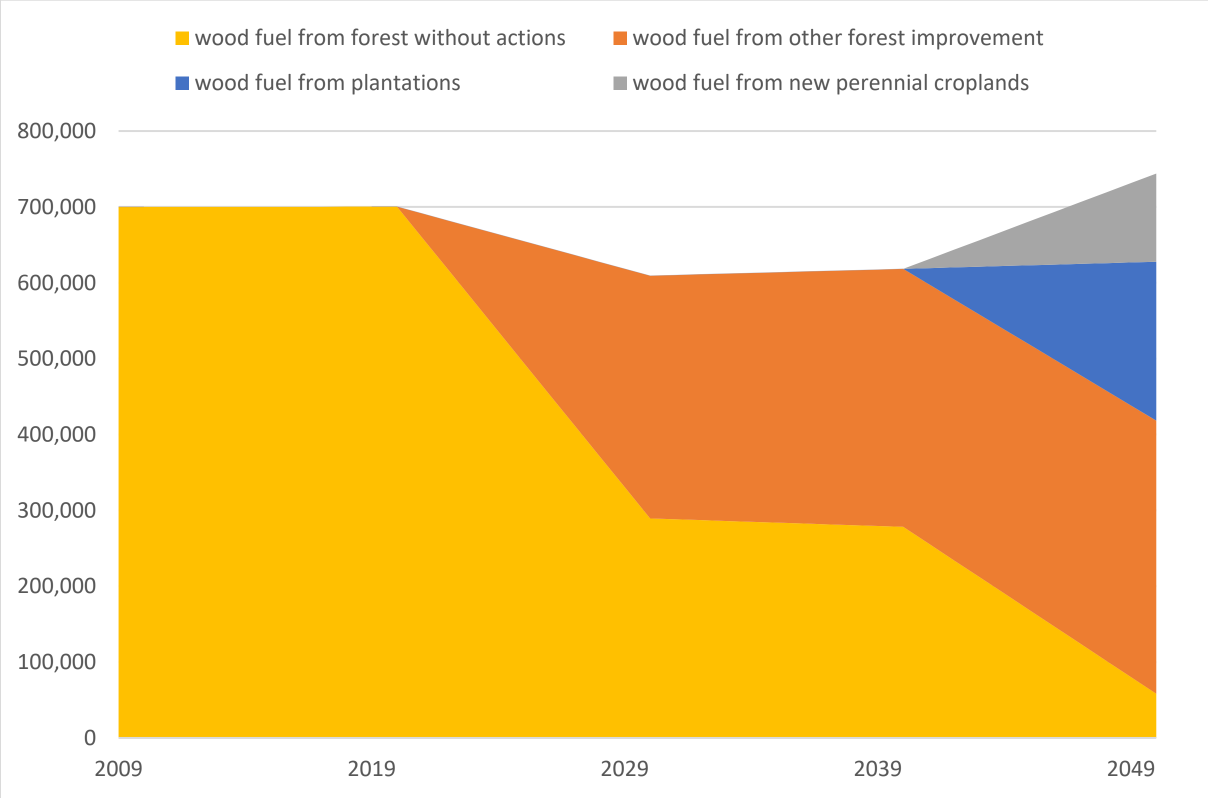

Figure 23 : Fuelwood production (m3/year) considering forest and crop actions.

6. Recommendations on strategy.

Recommendations may be summarized with the following key words:

Afforest and plant: Unsurprisingly, afforestation actions are the ones that have the most impact because the ambition chosen in this document is great with very important afforestation surfaces. This action is identified by national policies but is also expensive and difficult. Plantations on non-forest land often have mixed results and high mortality that should be considered. Plantations for orchards and agroforestry are also options that can generate additional sinks, it is difficult to estimate the actual possibilities but the feedbacks on these options were rather optimistic and the proposed expansion judged in line with national ambitions.

Restore forest and soils: The restoration of degraded forests seem easier to implement than new plantations because even degraded land has retained forest qualities. Trees can already be seeded or exist as shrubs, which promotes a faster recovery. In agriculture, the most significant measure seems to be the optimization of grasslands and the restoration of degraded soils, but it is also the most difficult action to carry out.

Optimize/improve forest cropland and grassland management: The optimization of forest management has smaller impact insofar as most of the area is already degraded and concerned by restoration, so possible good practices are already included in the action of restoration. In agriculture the possibilities of action are quite weak with the chosen assumptions, but this reflects a reality, it is difficult to strongly change the carbon stocks, especially in soils.

Regulate wood harvest: All regulations leading to a decrease of the harvesting rate in forest are effective and even necessary to manage the restoration of lands.

Conclusion

This study attempted to review a wide range of actions to reduce greenhouse gas emissions or promote sinks. The analysis is intended to be both quantitative and qualitative. Among the most striking results, it can be said that few actions have very strong emission reduction potential. In the forest, there is no way to force growth quickly and the limitation of harvest remains hypothetical. It is an indispensable resource for the population, so it offers few means of action (it is not possible to prevent wood harvesting until alternatives to wood are viable). In agriculture, the possible contribution of agroforestry or agricultural trees remains modest, and the contribution of soils is largely hypothetical.

The main option therefore remains to convert land to forest use (FOR1). This seems possible because large areas of grassland exist. These grasslands are used as pasture by livestock, but this extensive agriculture could be adapted to make way for additional wooded areas. The challenge of a change in land use remains immense when we consider the possible obstacles (ownerships...). This afforestation option has the advantage of generating a significant carbon sink due to the growth of trees over a big period and providing additional access to a wood resource. As part of this study, the sink generated by the additional afforestation of 250,000 ha over the period 2020-2050 is approaching 44 MtCO2eq over the entire period with a maximum annual sink around 2,000 ktCO2eq/year. This sink would certainly be extended beyond 2050 but certainly with slightly lower annual values due to the lower contribution of dead wood and litter pools after 20 years and regular wood harvest on these new forests.

On the existing forest areas three main actions have been tested, these three actions are linked and could perhaps have been managed jointly. These are the restoration of forest land (FOR2), the optimization of forest management (FOR3) and the reduction of wood energy harvest (FOR5) due to actions outside forests such as the promotion of alternative energies. Cumulatively, these three actions affect 330,000 ha of forests and generate an emission reduction of the order of 8.2 MtCO2eq over the entire period with a maximum annual sink reached in 2050 of about 900 ktCO2eq. This sink is most certainly expected to increase after 2050 as these restored forests benefit from the contribution of newly planted land for wood production and are therefore less subject to anthropogenic pressure.

In agriculture, with 50,000 ha of additional perennial crops (orchards), an interesting sink of the order of 1.7 MTCO2eq is reached over the period 2020-2050 with a maximum annual sink around 80 ktCO2eq/year. This sink remains much lower per unit of area than forests and in general does not last as long, wood harvests on orchards are very close to the annual growth level of these lands and the standing stock does not increase significantly after 20 years. The effect of this measure is therefore more limited in time.

Other actions are often mentioned as major, including the improvement of cultivation practices (AGR4 to AGR10 actions), however the tests remain ultimately inconclusive on their potential. By cumulating the estimated effects of AGR4 to AGR10 actions (on 266,000 ha), a cumulative reduction of the order of 1.3 MtCO2eq is achieved over the entire period with a maximum annual sink of around 60 ktCO2eq/year. It is not a huge amount. It must be said, however, that this estimate is very uncertain because both agricultural practices and carbon stocks present in the soil are poorly known. The estimation of possible changes in practices and their effect is therefore still very hypothetical. This report concludes that there is little potential for reduction on agricultural land, but this result is poorly supported by local knowledge. Agricultural lands usually generate significant sinks on land where stocks of organic matter have severely been degraded in the past and where actions make it possible to restore stocks. Little information on the condition of agricultural land could be collected and the proposed result should therefore be considered with caution.

In grasslands, the action of optimizing meadows makes it possible to achieve an interesting result with a cumulated sink over the period of 4 MtCO2eq and an annual maximum sink reached of the order of 200 ktCO2eq/year. This relatively large sink is estimated on the basis of a very large area (500 000 ha) subject to improvement measures. The actions to improve the management of grasslands are numerous, choice of seeds, period of grassing of animals, density of animals, choice between mowing and grazing. Unfortunately, the effect of these actions is not easy to estimate, and the IPCC method used to test this impact remains rough (based on stages of supposed degradation). Action on grasslands is a good way to reduce GHG emissions in Armenia because it seems that grasslands are largely degraded by pasture, so it would be possible to reverse the trend. But the ability to change this management, and the effect on soil carbon stocks, are still very hypothetical.

Finally, this study mentions other actions encountered in the literature, but their possible amplitude does not seem to be able to strongly impact the national balance (firefighting, limitation of peat extraction, increase in the life of wood materials, use of biochar ...). The fact remains that at the local level these actions can be extremely relevant, for issues that are very different from global climate issues.

Climate action is complex and cannot be overcome by other issues, which are often more visible or considered more critical in the short term. It is therefore by relying on synergies with other objectives that it is most likely to succeed. This is the case with afforestation actions that offer the possibility of providing additional wood. This is the case with orchard plantations that can correspond to a commercial opportunity for the country and a welcome provision for the population. Finally, this is the case for all agricultural land (cultivated land and meadows) whose fertility and productivity are strongly impacted by the quality of the soil, of which the level of organic matter is one of the main criteria.

It is also recalled that more accurate assessments require monitoring of the current situation, in forests where uncertainties in growth and harvest are cumulative and in agriculture where the estimates relate mainly to soil carbon for which modelling is difficult and in high demand for data.

Annex I
References

Buchner, J., Yin, H., Frantz, D., Kuemmerle, T., Askerov, E., Bakuradze, T., ... and Rizayeva, A. (2020). Land-cover change in the Caucasus Mountains since 1987 based on the topographic correction of multi-temporal Landsat composites. Remote Sensing of Environment, 248, 111967.

Canaveira, P., Manso, S., Pellis, G., Perugini, L., De Angelis, P., Neves, R., Papale, D., Paulino, J., Pereira, T., Pina, A., Pita, G., Santos, E., Scarascia-Mugnozza, G., Domingos, T., and Chiti, T. (2018). Biomass Data on Cropland and Grassland in the Mediterranean Region. Final Report for Action A4 of Project MediNet. http://www.lifemedinet.com/

Economy and values research center, (2007). The Economics of Armenia's Forest Industry https://ace.aua.am/files/2019/05/2007-EV-Forest-Industry-Report_Eng.pdf

FAOSTAT, 2021 http://www.fao.org/faostat

Ghazaryan, H. G., & Kroyan, S. Z. (2016). Genetic and agroindustrial features of meadow brown irrigated soils of Republic of Armenia in terms of climate change and desertification. *Annals of Agrarian Science*, *14*(4), 326-330.

IPCC 2006, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC, 2019: Summary for Policymakers. In: *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems* [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)].

IUCN (2016) International Union for Conservation of Nature Bonn Challenge. https://2016congress.iucn.org/news/20160316/bonn-challenge-forest-restoration.html

Khechoyan, M. S. (2018). Forest degradation and its expression in the territory of Republic of Armenia. Հայաստանի կենսաբանական հանդես Biological Journal of Armenia Биологический журнал Армении, 70(3), 97-101.

Moreno-Sanchez, R., & Sayadyan, H. Y. (2005). Evolution of the forest cover in Armenia. International Forestry Review, 7(2), 113-127.

Republic Of Armenia, Ministry Of Nature Protection, (2009). Fourth National Report to the Convention on Biological Diversity, Yerevan. Available at: https://www.cbd.int/doc/world/am/am-nr-04-en.pdf consulted on 31/12/2020

Republic of Armenia, Ministry of Nature Protection (2019). Sixth national report of the Republic of Armenia - Convention on biological diversity. 165 p.

Republic of Armenia, Ministry of Environment, (2020a) National Greenhouse Gas Inventory Report of Armenia 1990-2017. UNFCCC.

Republic of Armenia, Ministry of Environment, (2020b). Fourth National Communication on Climate Change. Yerevan. UNDP Armenia, 2020.-213p.

Rhoades, 2018. Impacts of Deforestation and Land Cover Change on Mountain Soils in Hrazdan, Armenia https://ace.aua.am/files/2019/05/2008-Jason-Rhoades-Impacts-of-deforestation-on-soils-in-Hrazdan.pdf

Sayadyan, H. Y., & Moreno-Sanchez, R. (2006). Forest policies, management and conservation in Soviet (1920–1991) and post-Soviet (1991–2005) Armenia. Environmental Conservation, 33(1), 60-72.

Thuresson, T., Drakenberg, B. & Ter-Gazaryan, K. 1999. Armenia Forest Resources Assessment - report on a sample-based forest resource assessment of the forests possible for exploitation in Armenia. Jönköping, Sweden, National Board of Forestry.

UNCCD, (2018) United Nations Convention to Combat Desertification:
https://prais.unccd.int/node/214

Annex II
Detailed results

Table 14 : Emissions reductions by action for the entire time series (kt CO2eq/year)

	FOR1	FOR2	AGR11	AGR1	LUC3g	AGR2	FOR3	FOR5	LUC3c	LUC2	AGR6	AGR9	AGR5	AGR8	AGR4	AGR10	LUC1
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0
2021	-107	-14	-10	-4	-4	-4	-2	0	-1	-2	-1	-2	-1	-1	-4	-3	0
2022	-215	-29	-21	-9	-9	-8	-3	0	-3	-4	-2	-3	-2	-1	-4	-3	0
2023	-322	-43	-31	-13	-13	-11	-5	0	-4	-5	-3	-5	-3	-2	-4	-3	0
2024	-429	-58	-41	-17	-17	-15	-6	0	-5	-7	-4	-7	-4	-2	-4	-3	0
2025	-537	-72	-51	-21	-22	-19	-8	0	-7	-9	-5	-8	-5	-3	-4	-3	0
2026	-644	-88	-62	-26	-26	-23	-9	0	-8	-11	-5	-10	-5	-3	-4	-3	0
2027	-751	-103	-72	-30	-30	-27	-11	0	-9	-13	-6	-12	-6	-4	-4	-3	0
2028	-858	-119	-82	-34	-35	-31	-13	0	-11	-15	-7	-13	-7	-4	-4	-3	0
2029	-966	-135	-93	-38	-39	-34	-14	0	-12	-16	-8	-15	-8	-5	-4	-3	0
2030	-1 073	-152	-103	-43	-43	-38	-16	0	-13	-18	-9	-17	-9	-5	-4	-3	0
2031	-1 180	-148	-113	-47	-48	-42	-17	0	-15	-18	-10	-17	-10	-5	-4	-3	0
2032	-1 288	-144	-123	-51	-52	-46	-19	0	-16	-18	-11	-17	-11	-5	-4	-3	0
2033	-1 395	-139	-134	-56	-56	-50	-20	0	-17	-18	-12	-17	-12	-5	-4	-3	0
2034	-1 502	-135	-144	-60	-60	-53	-21	0	-19	-18	-13	-17	-13	-5	-4	-3	0
2035	-1 610	-130	-154	-64	-65	-57	-22	0	-20	-18	-14	-17	-14	-5	-4	-3	0
2036	-1 717	-126	-165	-68	-69	-61	-23	0	-21	-18	-15	-17	-15	-5	-4	-3	0
2037	-1 824	-121	-175	-73	-73	-65	-25	0	-23	-18	-15	-17	-15	-5	-4	-3	0
2038	-1 932	-121	-185	-77	-78	-69	-26	0	-24	-18	-16	-17	-16	-5	-4	-2	0

	FOR1	FOR2	AGR11	AGR1	LUC3g	AGR2	FOR3	FOR5	LUC3c	LUC2	AGR6	AGR9	AGR5	AGR8	AGR4	AGR10	LUC1
2039	-2 039	-121	-195	-81	-82	-72	-27	0	-25	-18	-17	-17	-17	-5	-4	-1	0
2040	-2 146	-121	-206	-86	-86	-76	-29	0	-27	-18	-18	-17	-18	-5	-4	-1	0
2041	-2 168	-183	-206	-86	-82	-69	-31	-12	-25	-16	-18	-15	-17	-5	0	0	0
2042	-2 190	-246	-206	-86	-78	-62	-34	-24	-24	-15	-18	-13	-16	-4	0	0	0
2043	-2 211	-308	-206	-86	-73	-54	-36	-36	-23	-13	-18	-12	-15	-4	0	0	0
2044	-2 233	-371	-206	-86	-69	-47	-39	-48	-21	-11	-18	-10	-15	-3	0	0	0
2045	-2 254	-433	-206	-86	-65	-40	-41	-60	-20	-9	-18	-8	-14	-3	0	0	0
2046	-2 169	-496	-195	-81	-60	-32	-44	-72	-19	-7	-17	-7	-13	-2	0	0	0
2047	-2 083	-558	-185	-77	-56	-25	-46	-84	-17	-5	-16	-5	-12	-2	0	0	0
2048	-1 997	-620	-175	-73	-52	-18	-49	-96	-16	-4	-15	-3	-11	-1	0	0	0
2049	-1 912	-683	-165	-68	-48	-11	-51	-109	-15	-2	-15	-2	-10	-1	0	0	0
2050	-1 826	-745	-154	-64	-43	-3	-54	-121	-13	0	-14	0	-9	0	0	0	0
TOTAL	**-43 579**	**-6 761**	**-4 063**	**-1 689**	**-1 534**	**-1 163**	**-742**	**-663**	**-471**	**-366**	**-358**	**-336**	**-322**	**-109**	**-82**	**-51**	**-1**

Table 15 : Emissions /removals for LULUCF sector with actions for the entire time series (kt CO2eq/year)

	Forest remaining forest	Land converted to forest	Cropland remaining cropland	Land converted to cropland	Grassland remaining grassland	Land converted to grassland	Wetland remaining wetland	Land converted to wetland	Settlement remaining settlement	Land converted to settlement	Other land remaining other land	Land converted to other land	Total
2018	259	-250	-1	100	0	44	0	8	0	1	0	1	162
2019	256	-236	-1	93	0	37	0	8	0	0	0	1	157
2020	253	-221	-2	86	0	30	0	7	0	0	0	0	153
2021	237	-319	-19	79	-10	23	0	7	0	0	0	0	-1
2022	222	-416	-31	72	-21	16	0	7	0	0	0	0	-150
2023	206	-513	-43	66	-31	9	0	7	0	0	0	0	-299
2024	191	-611	-55	59	-41	2	0	7	0	0	0	0	-448
2025	175	-708	-67	52	-51	-5	0	7	0	0	0	0	-597
2026	160	-810	-79	45	-62	-12	0	7	0	0	0	0	-750
2027	146	-911	-92	37	-72	-18	0	7	0	0	0	0	-902
2028	131	-1013	-104	30	-82	-24	0	7	0	0	0	0	-1055
2029	116	-1115	-116	22	-93	-29	0	6	0	0	0	0	-1206
2030	102	-1216	-128	15	-103	-33	0	6	0	0	0	0	-1358
2031	97	-1309	-138	7	-113	-39	0	5	0	0	0	0	-1489
2032	93	-1401	-148	-1	-123	-45	0	4	0	0	0	0	-1621
2033	89	-1493	-158	-9	-134	-50	0	3	0	0	0	0	-1752
2034	84	-1586	-168	-17	-144	-56	0	2	0	0	0	0	-1884
2035	80	-1678	-177	-25	-154	-62	0	2	0	0	0	0	-2015
2036	75	-1770	-187	-33	-165	-68	0	1	0	0	0	0	-2146

	Forest remaining forest	Land converted to forest	Cropland remaining cropland	Land converted to cropland	Grassland remaining grassland	Land converted to grassland	Wetland remaining wetland	Land converted to wetland	Settlement remaining settlement	Land converted to settlement	Other land remaining other land	Land converted to other land	Total
2037	71	-1862	-197	-41	-175	-73	0	0	0	0	0	0	-2278
2038	70	-1970	-207	-42	-185	-78	0	0	0	0	0	0	-2412
2039	68	-2077	-216	-43	-195	-82	0	0	0	0	0	0	-2546
2040	67	-2184	-225	-45	-206	-86	0	0	0	0	0	0	-2679
2041	-31	-2184	-210	-42	-206	-82	0	0	0	0	0	0	-2755
2042	-130	-2184	-199	-39	-206	-78	0	0	0	0	0	0	-2836
2043	-229	-2184	-189	-35	-206	-73	0	0	0	0	0	0	-2917
2044	-328	-2184	-179	-32	-206	-69	0	0	0	0	0	0	-2998
2045	-426	-2184	-168	-29	-206	-65	0	0	0	0	0	0	-3078
2046	-525	-2077	-153	-26	-195	-60	0	0	0	0	0	0	-3036
2047	-624	-1970	-137	-23	-185	-56	0	0	0	0	0	0	-2994
2048	-722	-1862	-121	-20	-175	-52	0	0	0	0	0	0	-2952
2049	-821	-1755	-106	-16	-165	-48	0	0	0	0	0	0	-2911
2050	-920	-1648	-90	-13	-154	-43	0	0	0	0	0	0	-2869

Table 16 : Cumulative area concerned by actions (LUC, FOR, AGR) for the entire time series (ha)

Negative values are for actions of land use change preventions.

	LUC1	LUC2	LUC3c	LUC3g	FOR1	FOR2	FOR3	FOR4	FOR5	FOR6	FOR7
2021	-1	-2000	-100	-350	10000	20000	1000	0	0	0	0
2022	-2	-4000	-200	-700	20000	40000	2000	0	0	0	0
2023	-3	-6000	-300	-1050	30000	60000	3000	0	0	0	0
2024	-4	-8000	-400	-1400	40000	80000	4000	0	0	0	0
2025	-5	-10000	-500	-1750	50000	100000	5000	0	0	0	0
2026	-6	-12000	-600	-2100	60000	120000	6000	0	0	0	0
2027	-7	-14000	-700	-2450	70000	140000	7000	0	0	0	0
2028	-8	-16000	-800	-2800	80000	160000	8000	0	0	0	0
2029	-9	-18000	-900	-3150	90000	180000	9000	0	0	0	0
2030	-10	-20000	-1000	-3500	100000	200000	10000	0	0	0	0
2031	-11	-20000	-1100	-3850	110000	200000	11000	0	0	0	0
2032	-12	-20000	-1200	-4200	120000	200000	12000	0	0	0	0
2033	-13	-20000	-1300	-4550	130000	200000	13000	0	0	0	0
2034	-14	-20000	-1400	-4900	140000	200000	14000	0	0	0	0
2035	-15	-20000	-1500	-5250	150000	200000	15000	0	0	0	0
2036	-16	-20000	-1600	-5600	160000	200000	16000	0	0	0	0
2037	-17	-20000	-1700	-5950	170000	200000	17000	0	0	0	0
2038	-18	-20000	-1800	-6300	180000	200000	18000	0	0	0	0
2039	-19	-20000	-1900	-6650	190000	200000	19000	0	0	0	0
2040	-20	-20000	-2000	-7000	200000	200000	20000	0	0	0	0
2041	-21	-20000	-2000	-7000	210000	200000	21000	0	10000	0	0
2042	-22	-20000	-2000	-7000	220000	200000	22000	0	20000	0	0
2043	-23	-20000	-2000	-7000	230000	200000	23000	0	30000	0	0
2044	-24	-20000	-2000	-7000	240000	200000	24000	0	40000	0	0

	LUC1	LUC2	LUC3c	LUC3g	FOR1	FOR2	FOR3	FOR4	FOR5	FOR6	FOR7
2045	-25	-20000	-2000	-7000	250000	200000	25000	0	50000	0	0
2046	-26	-20000	-2000	-7000	250000	200000	26000	0	60000	0	0
2047	-27	-20000	-2000	-7000	250000	200000	27000	0	70000	0	0
2048	-28	-20000	-2000	-7000	250000	200000	28000	0	80000	0	0
2049	-29	-20000	-2000	-7000	250000	200000	29000	0	90000	0	0
2050	-30	-20000	-2000	-7000	250000	200000	30000	0	100000	0	0

	AGR1	AGR2	AGR4	AGR5	AGR6	AGR7	AGR8	AGR9	AGR10	AGR12_C	AGR13	AGR11	AGR12_G
2021	2000	5000	18000	5000	4000	0	3000	1000	8000	0	0	20000	0
2022	4000	10000	18000	10000	8000	0	6000	2000	8000	0	0	40000	0
2023	6000	15000	18000	15000	12000	0	9000	3000	8000	0	0	60000	0
2024	8000	20000	18000	20000	16000	0	12000	4000	8000	0	0	80000	0
2025	10000	25000	18000	25000	20000	0	15000	5000	8000	0	0	100000	0
2026	12000	30000	18000	30000	24000	0	18000	6000	8000	0	0	120000	0
2027	14000	35000	18000	35000	28000	0	21000	7000	8000	0	0	140000	0
2028	16000	40000	18000	40000	32000	0	24000	8000	8000	0	0	160000	0
2029	18000	45000	18000	45000	36000	0	27000	9000	8000	0	0	180000	0
2030	20000	50000	18000	50000	40000	0	30000	10000	8000	0	0	200000	0
2031	22000	55000	18000	55000	44000	0	30000	10000	8000	0	0	220000	0
2032	24000	60000	18000	60000	48000	0	30000	10000	8000	0	0	240000	0
2033	26000	65000	18000	65000	52000	0	30000	10000	8000	0	0	260000	0
2034	28000	70000	18000	70000	56000	0	30000	10000	8000	0	0	280000	0
2035	30000	75000	18000	75000	60000	0	30000	10000	8000	0	0	300000	0
2036	32000	80000	18000	80000	64000	0	30000	10000	8000	0	0	320000	0
2037	34000	85000	18000	85000	68000	0	30000	10000	8000	0	0	340000	0
2038	36000	90000	18000	90000	72000	0	30000	10000	8000	0	0	360000	0

	AGR1	AGR2	AGR4	AGR5	AGR6	AGR7	AGR8	AGR9	AGR10	AGR12_C	AGR13	AGR11	AGR12_G
2039	38000	95000	18000	95000	76000	0	30000	10000	8000	0	0	380000	0
2040	40000	100000	18000	100000	80000	0	30000	10000	8000	0	0	400000	0
2041	42000	105000	18000	100000	84000	0	30000	10000	8000	0	0	420000	0
2042	44000	110000	18000	100000	88000	0	30000	10000	8000	0	0	440000	0
2043	46000	115000	18000	100000	92000	0	30000	10000	8000	0	0	460000	0
2044	48000	120000	18000	100000	96000	0	30000	10000	8000	0	0	480000	0
2045	50000	125000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0
2046	50000	130000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0
2047	50000	135000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0
2048	50000	140000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0
2049	50000	145000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0
2050	50000	150000	18000	100000	100000	0	30000	10000	8000	0	0	500000	0

Table 17 : Area by land use for the entire time series (ha)

Area at the end of the year, with actions	Forest	Cropland	Grassland	Wetland	Settlement	Other land	**Total territory**
2018	350141	572619	1459550	9853	110307	471792	2974260
2019	350141	572618	1459550	9853	110308	471792	2974260
2020	350141	572617	1459550	9853	110309	471792	2974260
2021	360591	570517	1451200	9853	110309	471792	2974260
2022	371041	568417	1442850	9853	110309	471792	2974260
2023	381491	566317	1434500	9853	110309	471792	2974260
2024	391941	564217	1426150	9853	110309	471792	2974260
2025	402391	562117	1417800	9853	110309	471792	2974260
2026	412841	560017	1409450	9853	110309	471792	2974260
2027	423291	557917	1401100	9853	110309	471792	2974260
2028	433741	555817	1392750	9853	110309	471792	2974260
2029	444191	553717	1384400	9853	110309	471792	2974260
2030	454641	551617	1376050	9853	110309	471792	2974260
2031	465091	551517	1365700	9853	110309	471792	2974260
2032	475541	551417	1355350	9853	110309	471792	2974260
2033	485991	551317	1345000	9853	110309	471792	2974260
2034	496441	551217	1334650	9853	110309	471792	2974260
2035	506891	551117	1324300	9853	110309	471792	2974260
2036	517341	551017	1313950	9853	110309	471792	2974260
2037	527791	550917	1303600	9853	110309	471792	2974260
2038	538241	550817	1293250	9853	110309	471792	2974260
2039	548691	550717	1282900	9853	110309	471792	2974260
2040	559141	550617	1272550	9853	110309	471792	2974260
2041	569141	550617	1262550	9853	110309	471792	2974260
2042	579141	550617	1252550	9853	110309	471792	2974260

Area at the end of the year, with actions	Forest	Cropland	Grassland	Wetland	Settlement	Other land	**Total territory**
2043	589141	550617	1242550	9853	110309	471792	2974260
2044	599141	550617	1232550	9853	110309	471792	2974260
2045	609141	550617	1222550	9853	110309	471792	2974260
2046	609141	550617	1222550	9853	110309	471792	2974260
2047	609141	550617	1222550	9853	110309	471792	2974260
2048	609141	550617	1222550	9853	110309	471792	2974260
2049	609141	550617	1222550	9853	110309	471792	2974260
2050	609141	550617	1222550	9853	110309	471792	2974260

Table 18 : Parameters used for all actions with calculations based on carbon stock changes (LUC, FOR)

Pool	Parameter	Unit	LUC1		LUC2		LUC3_C		LUC3_G	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Biomass	Average annual above-ground biomass growth (Gw)	t.dm/ha								
Biomass	Root to shoot (R)	no unit								
Biomass	C content	tC/td.m								
Wood removal	Amount of wood removed	m3/yr/ha								
Wood removal	BCEFR	no unit								
Wood removal	Root to shoot (R)	no unit								
Wood removal	C content	tC/td.m								
Wood removal	total amount in C	tC/yr								
Fuel wood	Amount of wood removed	m3/yr/ha								
Fuel wood	BCEFR	no unit								
Fuel wood	Root to shoot (R)	no unit								
Fuel wood	C content	tC/td.m								
Fuel wood	total amount in C	tC/yr/ha								
Biomass	Evolution of stock	tC/yr/ha								
Biomass	Initial use : Above ground biomass	t.dm/ha	10	0	13.6	10	70.527	10	70.527	13.6
Biomass	Initial use : Ration of below-ground biomass to above-ground biomass	no unit	0	0	0	0	0.23	0	0.23	0
Biomass	Initial use : Carbon fraction	tC/td.m	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting initial use	tC/ha	4.7	0	6.392	4.7	40.77166	4.7	40.77166	6.392
Biomass	Final use : Above ground biomass	t.dm/ha	0	0	10	10	10	10	13.6	13.6
Biomass	Final use : Ration of below-ground biomass to above-ground biomass	no unit	0	0	0	0	0	0	0	0
Biomass	Final use : Carbon fraction	tC/td.m	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting final use	tC/ha	0	0	4.7	4.7	4.7	4.7	6.392	6.392
Biomass	Evolution of stock	tC/yr/ha	0.235	0	0.0846	0	1.803583	0	1.718983	0
Litter	Stock - Initial use	tC/ha	0	0	0	0	28	0	28	0
Litter	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0
Litter	Evolution of stock	tC/yr	0	0	0	0	1.4	0	1.4	0
Deadwood	Stock - Initial use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Evolution of stock	tC/yr/ha	0	0	0	0	0	0	0	0
Soils	Initial use : Stock ref	tC/ha	33	33	33	33	33	33	33	33

Pool	Parameter	Unit	LUC1		LUC2		LUC3_C		LUC3_G	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Soils	Initial use : F - land use	tC/ha	0.75	0.5	0.85	0.75	1	0.75	1	0.85
Soils	Initial use : F - management	tC/ha	1	1	1	1	1	1	1	1
Soils	Initial use : F - input	tC/ha	1	1	1	1	1	1	1	1
Soils	Resulting initial use	tC/ha	24.75	16.5	28.05	24.75	33	24.75	33	28.05
Soils	Final use : Stock ref	tC/ha	33	33	33	33	33	33	33	33
Soils	Final use : F - land use	tC/ha	0.5	0.5	0.75	0.75	0.75	0.75	0.85	0.85
Soils	Final use : F - management	tC/ha	1	1	1	1	1	1	1	1
Soils	Final use : F - input	tC/ha	1	1	1	1	1	1	1	1
Soils	Resulting Final use	tC/ha	16.5	16.5	24.75	24.75	24.75	24.75	28.05	28.05
Soils	Evolution of stock	tC/yr/ha	0.4125	0	0.165	0	0.4125	0	0.2475	0
Biomass + Litter + Deadwood + Soils	Evolution of stock	tC/yr/ha	0.6475	0	0.2496	0	3.616083	0	3.366483	0
	Emissions/removals associated	**t CO2e/yr/ha**	-2.37417	0	-0.9152	0	-13.259	0	-12.3438	0

Pool	Parameter	Unit	FOR1		FOR2		FOR3		FOR5	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Biomass	Average annual above-ground biomass growth (Gw)	t.dm/ha	2.166667	2.166667	0.8355	2	1.5	2	0.8355	0.8355
Biomass	Root to shoot (R)	no unit	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Biomass	C content	tC/td.m	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Wood removal	Amount of wood removed	m3/yr/ha	0	0	0	0	0	0	0	0
Wood removal	BCEFR	no unit	0.557	0.557	0.557	0.557	0.557	0.557	0.557	0.557
Wood removal	Root to shoot (R)	no unit	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Wood removal	C content	tC/td.m	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Wood removal	total amount in C	tC/yr	0	0	0	0	0	0	0	0
Fuel wood	Amount of wood removed	m3/yr/ha	0	2.094554	1.5	1	2	2	0	0
Fuel wood	BCEFR	no unit	0.557	0.557	0.557	0.557	0.557	0.557	0.557	0.557
Fuel wood	Root to shoot (R)	no unit	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
Fuel wood	C content	tC/td.m	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Fuel wood	total amount in C	tC/yr/ha	0	0.6888	0.493279	0.328853	0.657706	0.657706	0	0
Biomass	Evolution of stock	tC/yr/ha	1.2792	0.5904	0	0.851947	0.227894	0.523094	0.493279	0.493279
Biomass	Initial use : Above ground biomass	t.dm/ha								

Pool	Parameter	Unit	FOR1		FOR2		FOR3		FOR5	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Biomass	Initial use : Ration of below-ground biomass to above-ground biomass	no unit								
Biomass	Initial use : Carbon fraction	tC/td.m								
Biomass	Resulting initial use	tC/ha								
Biomass	Final use : Above ground biomass	t.dm/ha								
Biomass	Final use : Ration of below-ground biomass to above-ground biomass	no unit								
Biomass	Final use : Carbon fraction	tC/td.m								
Biomass	Resulting final use	tC/ha								
Biomass	Evolution of stock	tC/yr/ha								
Litter	Stock - Initial use	tC/ha	0	28	28	28	28	28	28	28
Litter	Stock - Final use	tC/ha	28	28	28	28	28	28	28	28
Litter	Evolution of stock	tC/yr	1.4	0	0	0	0	0	0	0
Deadwood	Stock - Initial use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Evolution of stock	tC/yr/ha	0	0	0	0	0	0	0	0
Soils	Initial use : Stock ref	tC/ha	33	33	33	33	33	33	33	33
Soils	Initial use : F - land use	tC/ha	0.85	1	1	1	1	1	1	1
Soils	Initial use : F - management	tC/ha	1	1	1	1	1	1	1	1
Soils	Initial use : F - input	tC/ha	1	1	1	1	1	1	1	1
Soils	Resulting initial use	tC/ha	28.05	33	33	33	33	33	33	33
Soils	Final use : Stock ref	tC/ha	33	33	33	33	33	33	33	33
Soils	Final use : F - land use	tC/ha	1	1	1	1	1	1	1	1
Soils	Final use : F - management	tC/ha	1	1	1	1	1	1	1	1
Soils	Final use : F - input	tC/ha	1	1	1	1	1	1	1	1
Soils	Resulting Final use	tC/ha	33	33	33	33	33	33	33	33
Soils	Evolution of stock	tC/yr/ha	0.2475	0	0	0	0	0	0	0
Biomass + Litter + Deadwood + soils	Evolution of stock	tC/yr/ha	2.9267	0.5904	0	0.851947	0.227894	0.523094	0.493279	0.493279
	Emissions/removals associated	**t CO2e/yr/ha**	-10.7312	-2.1648	0	-3.12381	-0.83561	-1.91801	-1.80869	-1.80869

Table 19 : Parameters used for all actions with calculations based on carbon stock changes (AGR1-AGR11)

Pool	**Parameter**	**Unit**	**AGR1**		**AGR2**		**AGR4**		**AGR5**		**AGR6**	
			<20 years	**>20 years**	**<20 years**	**>20 years**	**<20 years**	**>20 years**	**<20 years**	**>20 years**	**<20 years**	**>20 years**
Biomass	Average annual above-ground biomass growth (Gw)	t.dm/ha	0	0.925	0	0.25						
Biomass	Root to shoot (R)	no unit	0	0.23	0	0.23						
Biomass	C content	tC/td.m	0	0.48	0	0.48						
Wood removal	Amount of wood removed	m3/yr/ha	0	0	0	0						
Wood removal	BCEFR	no unit	0	0.557	0	0.557						
Wood removal	Root to shoot (R)	no unit	0	0.23	0	0.23						
Wood removal	C content	tC/td.m	0	0.48	0	0.48						
Wood removal	total amount in C	tC/yr	0	0	0	0						
Fuel wood	Amount of wood removed	m3/yr/ha	0	1.660682	0	0.448833						
Fuel wood	BCEFR	no unit	0	0.557	0	0.557						
Fuel wood	Root to shoot (R)	no unit	0	0.23	0	0.23						
Fuel wood	C content	tC/td.m	0	0.48	0	0.48						
Fuel wood	total amount in C	tC/yr/ha	0	0	0	0						
Biomass	Evolution of stock	tC/yr/ha	0	0	0	0						
Biomass	Initial use : Above ground biomass	t.dm/ha					10	10	10	10	10	10
Biomass	Initial use : Ration of below-ground biomass to above-ground biomass	no unit					0	0	0	0	0	0
Biomass	Initial use : Carbon fraction	tC/td.m					0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting initial use	tC/ha					4.7	4.7	4.7	4.7	4.7	4.7
Biomass	Final use : Above ground biomass	t.dm/ha					10	10	10	10	10	10

Pool	Parameter	Unit	AGR1		AGR2		AGR4		AGR5		AGR6	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Biomass	Final use : Ration of below-ground biomass to above-ground biomass	no unit					0	0	0	0	0	0
Biomass	Final use : Carbon fraction	tC/td.m					0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting final use	tC/ha					4.7	4.7	4.7	4.7	4.7	4.7
Biomass	Evolution of stock	tC/yr/ha					0	0	0	0	0	0
Litter	Stock - Initial use	tC/ha	0	0	0	1.4	0	0	0	0	0	0
Litter	Stock - Final use	tC/ha	0	0	1.4	1.4	0	0	0	0	0	0
Litter	Evolution of stock	tC/yr	0	0	0.07	0	0	0	0	0	0	0
Deadwood	Stock - Initial use	tC/ha	0	0	0	0	0	0	0	0	0	0
Deadwood	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0	0	0
Deadwood	Evolution of stock	tC/yr/ha	0	0	0	0	0	0	0	0	0	0
Soils	Initial use : Stock ref	tC/ha	33	33	33	33	33	33	33	33	33	33
Soils	Initial use : F - land use	tC/ha	0.75	0.8	0.75	0.7625	0.75	0.75	0.75	0.75	0.75	0.75
Soils	Initial use : F - management	tC/ha	1	1	1	1	0.95	1	1	1.04	1	1
Soils	Initial use : F - input	tC/ha	1	1	1	1	1	1	1	1	0.95	1
Soils	Resulting initial use	tC/ha	24.75	26.4	24.75	25.1625	23.5125	24.75	24.75	25.74	23.5125	24.75
Soils	Final use : Stock ref	tC/ha	33	33	33	33	33	33	33	33	33	33
Soils	Final use : F - land use	tC/ha	0.8	0.8	0.7625	0.7625	0.75	0.75	0.75	0.75	0.75	0.75
Soils	Final use : F - management	tC/ha	1	1	1	1	1	1	1.04	1.04	1	1
Soils	Final use : F - input	tC/ha	1	1	1	1	1	1	1	1	1	1
Soils	Resulting Final use	tC/ha	26.4	26.4	25.1625	25.1625	24.75	24.75	25.74	25.74	24.75	24.75
Soils	Evolution of stock	tC/yr/ha	0.0825	0	0.020625	0	0.061875	0	0.0495	0	0.061875	0
Biomass + Litter + Deadwood + soils	Evolution of stock	tC/yr/ha	0.58305	0	0.208125	0	0.061875	0	0.0495	0	0.061875	0
	Emissions/removals associated	**t CO2e/yr/ha**	-2.13785	0	-0.76313	0	-0.22688	0	-0.1815	0	-0.22688	0

Pool	Parameter	Unit	AGR8		AGR9		AGR10		AGR11	
			<20 years	>20 years	<20 years	>20 years	<20 years	>20 years	<20 years	>20 years
Biomass	Average annual above-ground biomass growth (Gw)	t.dm/ha								
Biomass	Root to shoot (R)	no unit								
Biomass	C content	tC/td.m								
Wood removal	Amount of wood removed	m3/yr/ha								
Wood removal	BCEFR	no unit								
Wood removal	Root to shoot (R)	no unit								
Wood removal	C content	tC/td.m								
Wood removal	total amount in C	tC/yr								
Fuel wood	Amount of wood removed	m3/yr/ha								
Fuel wood	BCEFR	no unit								
Fuel wood	Root to shoot (R)	no unit								
Fuel wood	C content	tC/td.m								
Fuel wood	total amount in C	tC/yr/ha								
Biomass	Evolution of stock	tC/yr/ha								
Biomass	Initial use : Above ground biomass	t.dm/ha	10	10	10	10	10	10	13.6	13.6
Biomass	Initial use : Ration of below-ground biomass to above-ground biomass	no unit	0	0	0	0	0	0	0	0
Biomass	Initial use : Carbon fraction	tC/td.m	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting initial use	tC/ha	4.7	4.7	4.7	4.7	4.7	4.7	6.392	6.392
Biomass	Final use : Above ground biomass	t.dm/ha	10	10	10	10	10	10	13.6	13.6
Biomass	Final use : Ration of below-ground biomass to above-ground biomass	no unit	0	0	0	0	0	0	0	0
Biomass	Final use : Carbon fraction	tC/td.m	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Biomass	Resulting final use	tC/ha	4.7	4.7	4.7	4.7	4.7	4.7	6.392	6.392
Biomass	Evolution of stock	tC/yr/ha	0	0	0	0	0	0	0	0
Litter	Stock - Initial use	tC/ha	0	0	0	0	0	0	0	0
Litter	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0
Litter	Evolution of stock	tC/yr	0	0	0	0	0	0	0	0
Deadwood	Stock - Initial use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Stock - Final use	tC/ha	0	0	0	0	0	0	0	0
Deadwood	Evolution of stock	tC/yr/ha	0	0	0	0	0	0	0	0

Pool	Parameter	Unit	AGR8		AGR9		AGR10		AGR11	
			<20 years	**>20 years**	**<20 years**	**>20 years**	**<20 years**	**>20 years**	**<20 years**	**>20 years**
Soils	Initial use : Stock ref	tC/ha	33	33	33	33	33	33	33	33
Soils	Initial use : F - land use	tC/ha	0.75	0.75	0.75	0.75	0.75	0.75	0.85	0.85
Soils	Initial use : F - management	tC/ha	1	1	1	1	1	1	0.9	1
Soils	Initial use : F - input	tC/ha	1	1.04	1	1.37	1.04	1.11	1	1
Soils	Resulting initial use	tC/ha	24.75	25.74	24.75	33.9075	25.74	27.4725	25.245	28.05
Soils	Final use : Stock ref	tC/ha	33	33	33	33	33	33	33	33
Soils	Final use : F - land use	tC/ha	0.75	0.75	0.75	0.75	0.75	0.75	0.85	0.85
Soils	Final use : F - management	tC/ha	1	1	1	1	1	1	1	1
Soils	Final use : F - input	tC/ha	1.04	1.04	1.37	1.37	1.11	1.11	1	1
Soils	Resulting Final use	tC/ha	25.74	25.74	33.9075	33.9075	27.4725	27.4725	28.05	28.05
Soils	Evolution of stock	tC/yr/ha	0.0495	0	0.457875	0	0.086625	0	0.14025	0
Biomass + Litter + Deadwood + soils	Evolution of stock	tC/yr/ha	0.0495	0	0.457875	0	0.086625	0	0.14025	0
	Emissions/removals associated	**t CO2e/yr/ha**	-0.1815	0	-1.67888	0	-0.31763	0	-0.51425	0