With the contribution of the LIFE financial instrument of the European Community

LIFE15 CCM/IT/000123

Final report on SheepToShip LIFE environmental impacts

D.1 Monitoring of environmental impacts

May 2021

Language: EN

CNR-IBE Institute of Bioeconomy

ISPAAM

Agris

Laore

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

uniss agraria

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Authors

CNR IBE / ISPAAM

Delia Cossu (IBE)
Enrico Vagnoni (IBE)
Pasquale Arca (IBE)
Antonello Franca (ISPAAM)
Pierpaolo Duce (IBE)

Agris Sardegna

Giovanni Molle
Mauro Decandia
Gabriella Serra

Laore Sardegna

Alberto Manca
Domenico Usai

UNISS - Dipartimento di Agraria

Alberto Atzori
Paola Sau
Mondina Lunesu

Coordinated by

CNR IBE

Institute of BioEconomy

Summary

Executive summary

SheepToShip LIFE project aim is the 20% reduction in 10 years of greenhouse gases (GHG) emissions (N_2O, CH_4, and CO_2) of Sardinian dairy sheep supply chain. Monitoring actions are oriented to evaluate the effectiveness of the project strategy, both in qualitative and quantitative terms. Mitigation measures proposed by the project, involving animal management, animal feed production and feed crop cultivation management, were implemented in 10 demonstrative farms. Improvements on GHG emissions were registered through a Life Cycle Assessment (LCA) analysis comparison between the pre and the post intervention situation. It is supposed that, at the project ending, 7% of Sardinian farms implemented the eco-innovation techniques proposed by the project. Results presented in this monitoring report show that, with 7% of the farms applying project mitigation strategies, the entire Sardinia supply chain greenhouses gases potential reduction is estimate in 2.724 $kgCO_2eq$ for methane, 347 kgCO2eq for N_2O and 866 $kgCO_2$ for carbon dioxide. The implementation of feed crop cultivation management measures has also a positive effect on soil carbon sequestration (Cseq) value, with an improvement higher than 100%.

Introduction

Agriculture and livestock farming contribute for 24% to greenhouse gas emissions, representing the second most impacting economic activity after the energy sector. Considering only methane and nitrous oxide emissions, they even become the major contributors.

SheepToShip LIFE intends to contribute in a concrete way to the objectives of the EU regarding the fight against climate change, presenting itself as an initiative aimed at reducing greenhouse gas emissions (GHG) in the agro-livestock sector and in the agri-food industry. In particular, the project's main objective is the 20% reduction in 10 years of GHG emissions (N_2O, CH_4, and CO_2) of the sheep sector in Sardinia. For this purpose, demonstration actions (Action C.3. Livestock and dairy farm models) have been planned on few model study cases (10 dairy farms). These actions intend introduce eco-innovative production strategies in this sector, to make a comparison between these strategies and the traditional management systems.

Monitoring activity, which have the aim of collecting information on the trend of the project, is very important. In fact, the monitoring action is oriented to evaluate the effectiveness of the project strategy, both in qualitative and quantitative terms, and to give essential feedbacks to the project cycle management process verifying the achievement of the established objectives and giving a harmonized methodological reference to project members and followers/stakeholders.

1. Monitoring Plan

The SheepToShip LIFE monitoring plan (Action D.1.) is addressed to assess the impact of all project activities aimed to improve the efficiency and the environmental performances of the Sardinian dairy supply chain.

The hotspots of dairy sheep production systems are individuated through an LCA analysis carried out on 18 farms studied by SheepToShip LIFE action C.1., successively were identified the mitigation strategies aimed to reduce the environmental impacts of the sheep milk production (action C.2.). Through action C.3. ten farms were selected for the implementation of the mitigation techniques (demonstrative actions):

- A15 – Sassari;
- A14 – Alghero;
- A13 – Ozieri;
- A8 – Bottida;
- A16 – Baesia, Pianu Ladu;
- A4 – Bonorva;
- A17 – Villamassargia;
- A19 – Decimoputzu;
- A5 – Borore;
- A20 – Villamassargia;

The elaboration of mitigation scenarios was done through the realization of on-site measures and estimates on the effects of the mitigation measures adopted by the selected farms, and with direct exchanges with farmers, for the collection of quantitative or qualitative information related to the project progress.

The data collected in these phases were used to measure the environmental performance as direct (operational) parameters, and indirect parameters, derived from an estimate through the implementation of an LCA analysis along the monitoring period.

For the construction of the LCA model and the calculations of the impacts, Simapro software was used (Pré Consultants, 2018), utilizing *Environmental Footprint 2.0 (adapted)* method.

The results collected about the mitigation activities in the demonstrative farms are later considered in a general estimate, about the implementation of the techniques proposed by the project on a larger scale, including farms that, persuaded by the communication and dissemination strategies of the project (action E) and the involved farmers feedback, decided to adopt the techniques illustrated by SheepToShip LIFE in their own farms.

The last step of the monitoring plan is to make a comparison between the pre and the post intervention situation, assess the effectiveness of the eco-innovative solutions proposed by the project and to estimate the environmental benefit achievable by the entire Sardinian dairy supply chain.

2. Mitigation Strategies

Mitigation actions proposed by SheepToShip LIFE project and tasted in the demonstrative farms in Action C.3. can be classified based on the targeted hotspot:

- Animal management.
- Animal feed production.
- Feed crop cultivation management.

2.1. Animal Management

Strategies about flock management are aimed at increasing animals reproductive and productive efficiency. Through these actions it is possible reducing the carbon footprint value for every kg of fat and protein corrected milk by increasing milk production. This action does not impact directly on GHG emission sources.

To increase the reproductive efficiency, "Sementusa" type protocol application is applied. It provides for various interventions in flock reproductive management, aimed at bringing average total fertility up to 98-99%, in order to increase the number of pregnant ewes that will consequently be able to produce milk. In that way the number of non-productive animals, that contribute to GHG emissions not amortized by the milk production, decrease.

A rise of production efficiency could be achieved by the identification and elimination of the less productive animals, their low milk production in fact do not adequately compensate their GHGs emissions. This action can be carried out through individual production controls with external services or the use of flowmeter facility systems.

2.2. Animal feed management

Animal feed strategies carried out by SheepToShip LIFE project operate as indirect actions, intervening on feed production techniques (on-farm feed production chain) and direct actions, reducing GHG emissions by modifying some characteristics of the feed ration, or by introducing supplements to reduce methanogenesis.

Indirect mitigation actions led to the increase of the farm area destined to forage cultivation. Making a better utilization of unused or under exploited areas permits to reduce off-farm purchased feed and their related carbon footprint.

Replace a portion of protein concentrates in feed ration with legume forages grown on-farm has a double effect: the reduction in methanogenesis due to legumes integrated inside the feed ration and the reduction of the carbon footprint related to off-farm purchased protein concentrates.

Another animal feed strategy proposed involves the integration in the feed ration of feed blocks made of molasses and lipids. These supplements allow to compensate the nutritional deficit of poor forages by increasing its digestibility and providing to the animal a series of vitamins and minerals.

Innovative haymaking techniques are introduced by the project to improve farm forage quality. The interventions were focused on the management of haymaking and especially on the identification of the best cutting temporal windows for hay production and on the production of alternative hays (wrapped bale silage) in order to: increase on-farm hay quality and preserve them under adverse weather conditions.

2.3. Feed crop cultivation management

Mitigation strategies on feed crop cultivation management are focused on farmland cultivated with annual forage, characterized by an intensive land use and fuel consumption.

Actions proposed by the project consist in the partially conversion of the farm area cultivated with arable fodder crops with improved pastures (permanent grassland) characterized by perennial and self-seeding species, lasting minimum 3 years, or Sulla biennial crop (Hedysarum coronarium); in the replacement of part natural pasture with an improved natural pasture; and in the use of "innovative low impact operations" like minimum tillage/sowing in rows and sod seeding.

These techniques, involving a lower soil exploitation, lead to an increase in soil carbon sequestration value and so to a higher soil carbon storing capacity.

3. Demonstrative Farms

Demonstrative farms were selected through a process of characterization of the island production systems, identification of the production areas that represent for the better these systems, and a subsequent sampling of the farms characterized.

A brief description of the selected farms, their hotspots and mitigation measures in each adopted is presented below.

A15

A15 farm is located in the north-west of Sardinia, the consistency of the flock is between 200-400 heads and the stocking rate range is 3-6 head ha^{-1}. A15 farm covers a total area of 74,7 ha, around 11 ha of which are irrigated, consisting mainly of autumn-winter herbages. The soil is sedimentary. The hotspot of A15 farm is mainly represented by the high percentage of cultivated land with annual forage crops, that determines high economic costs, diesel consumption and working time.

Mitigation actions proposed by the project established the cultivation of artificial pastures, a mixture of perennial and annual self-reseeding grasses and legume species, and Sulla (Hedysarum coronarium), on area previously occupied by annual crops, in irrigate condition. Consequently, specific agricultural techniques to allow the Sulla biennial crop and the artificial pasture establishment and persistence were adopted.

A14

A14 farm belongs to the group of farms with a stocking rate of 3-6 animals ha^{-1} and a flock size of 200-400 heads in production. It is located in the mountain relief of Monteforte, in the North-Ovest part of Sardinia. The area is characterized by considerable slopes and by soils with an acidic pH. Riu farm covers a total area of 51.8 ha, mostly occupied by natural pastures with a strong presence of mediterranean maquis, and partially cultivated with autumn-winter herbages.

The hotspot of A14 farm is mainly represented by the low feed self-sufficiency, that is why through the project was implemented the cultivation of artificial pastures in a 5 ha area with slope, previously occupied by annual crops, using a mixture of perennial and self-reseeding grasses and legumes species, suitable for the site pedoclimatic conditions. To do so, specific agricultural techniques were adopted to allow the artificial pasture establishment and persistence, in order to reduce the soil tillage operations and reduce the carbon footprint.

A13

A13 farm has a stocking rate of 3-6 head/ha and a flock consistency greater than 400 productive heads. It is located in the plain of Chilivani, an area situated in the Center-North of Sardinia, a territory characterized by sedimentary soils. A13 farm covers a total area of 132,4 ha, consisting mainly of natural pastures. Part of the land is cultivated with autumn-winter herbages. The area is not irrigated.

The hotspots of A13 farm are identified mainly in a low feed self-sufficiency, a low forage quality, a low productivity of the natural pastures and in a critical presence of weeds.

Project mitigation action were focused on pasture improvement interventions, through weed control (mowing and mulching) and in over seeding of perennial and annual self-reseeding grass-legume mixture.

A5

A5 farm is situated in the municipality of Borore, Centrum-West of Sardinia. It has between 200 and 400 productive animals, with a stocking rate in the 6-9 animals/ha range.

The area consists of 58,5 ha not irrigated, mainly invested as natural pasture, with a little portion cultivated with autumn-winter herbages.

Hotspots of A5 farm are low feed self- sufficiency and low forage quality and productivity of natural pastures. The intervenes planned by the project intend to replace the degraded natural pasture with improved perennial pasture and the annual forage crop with the perennial pasture.

A16

A16 farm counts more than 400 productive animals, with a stocking rate between 6 and 9 animals/ha. It is located in the municipality of Ozieri, in the Center-North of Sardinia. The farm covers 70,3 ha of plain, not irrigated. The area is characterized by sedimentary soils with neutral reaction.

The hectares of the farm are almost totally invested in autumn-winter herbals and irrigated grass of corn, with a lower part reserved for Sulla cultivation.

The hotspot of A16 farm, where the project has intervened, concerns the low on-farm hay quality. The interventions were focused on the management of haymaking, especially on the identification of the best cutting temporal windows for hay production and on the production of alternative hays (wrapped bale silage) in order to: increase on-farm hay quality and preserve them under adverse weather conditions.

A8

A8 farm is situated on granite substrate, in the municipality of Bottida, in the center of Sardinia. It has a stocking rate of 3-6 head ha-1 and a flock consistency of 200-400 heads in production. The area is not irrigated and has a declive conformation typical of mountain areas, soils are acidic and sub-acidic. A8 farm belongs to the category of forestry farms, and covers a total area of 79.3 ha, mainly invested in natural pasture, while a small portion of the extension is planted with autumn-winter herbals.

The hotspots of A8 farm are identified on low forage quality and productivity of natural pastures and low ewe fertility, especially for ewes lamb selected for replacement. To improve the environmental performance of the farm, SheepToShip carried on two measures: natural pasture interventions in part of the farm area (with over seeding of perennial and self-reseeding grass-legume mixture) and the improvement of reproductive performance with a veterinary consulting service for the application of “Sementusa protocol ®”, based on monitoring and operative interventions on ewes and rams.

A17

A17 farm is located in Villamassargia, in the South-West of Sardinia, the consistency of the flock is between 200-400 heads and the stocking rate range is 3-6 head ha^{-1}. Farm area is 64,2 ha covered with autumn-winter herbaceous plants, not irrigated. Hotspots found in A17 farm consist in poor quality of on-farm made hay, high neonatal mortality, moderately low milk yield, high soil tillage intensity and fuel consumption.
To face the hotspots listed above and improve the environmental performance of the farm, the project proposed the following mitigation actions: use of feed blocks containing molasses and urea in order to increase the digestibility of the roughage, application of "Sementusa protocol ®" to improve the reproduction performance of the flock, establishment of Sulla biennial crop and pasture improvement by overseeding of a perennial and self-reseeding grass-legume mixture in order to reduce the soil tillage intensity and hence the carbon footprint.

A19

A19 farm has a stocking rate of more than 9 head/ha and a flock consistency between 200 and 400 productive heads. It is located in the municipality of Decimoputzu, in the Center-South of Sardinia.
The farm is situated on a plain with a total area of 59.8 ha, irrigable, invested totally in autumn-winter herbals. The hotspot of A19 farm is the high percentage of tilled land every year, that means an high soil tillage intensity and a huge fuel consumption. As a mitigation action, the project To establish a persistent pasture, reduce soil tillage intensity and hence the carbon footprint introduced a persistent pasture, in order to reduce the soil tillage intensity and improve the carbon footprint value.

A20

A20 farm is located in the South-West of Sardinia, in Villamassargia municipality, the consistency of the flock is greater than 400 heads and the stocking rate range is 6-9 head ha^{-1}.
The farm has a total area of 189,1 ha, potentially irrigable, completely covered of autumn-winter herbals.
A20 farm is affected by a low fertility and low concentration of lambings. This means that many ewes lamb born late in winter, with lower return from meat (low lamb price after Christmas) and also a lower return from milk caused by the decay of forage quality in spring.
"Sementusa protocol ®" was implemented by the project to improve this aspect through a veterinary consulting service and ecography, to evaluate the reproduction performance of the flock along the reproductive season.
Other hotspots of the farm are identified in a high footrot incidence, treated by the project through vaccination and adequate prophylaxis by a vet assistance service, and a low feed self-sufficiency which led to the implementation of Sulla biennal crop in a portion of the farm area and in a minimum tillage/sowing and sod seeding technologies implementation.

A4

A4 farm belongs to the group of farms with a stocking rate of 3-6 animals ha^{-1} and a flock size of more than 400 heads in production. It is located in Bonorva, in the West-Central part of Sardinia. It is a

silvopastoral farm and covers a total area of 184 ha, all occupied by wooded natural pasture. The area is flat, the soils have sub-acid and acid reaction and are not irrigated.

The hotspots of A4 farm are identified in a decay of late summer pasture quality and low quality of on-farm made hay, reason why the use of feed blocks containing molasses and urea is proposed by the project in order to increase the digestibility of the roughage and in a bad animal management. Veterinary consulting service for the application of “Sementusa protocol ®”, vaccination and adequate prophylaxis was planned.

4. Mitigation Effects

During action C.3. of SheepToShip LIFE, the mitigation strategies planned by the project were implemented on demonstrative farms, based on their respective hotspots, and consequently GHG potential reduction for each intervention proposed was verified.

The percentage of carbon footprint reduction is deduced from the comparison between the pre and the post intervention situation, calculated through the implementation of an LCA analysis with Simapro software, utilizing 1 kg of fat and protein corrected milk (FPCM) as functional unit.

The elaboration of mitigation scenarios was done through the realization of on-site measures and estimates on the effects of the mitigation measures adopted by the selected farms, and with direct exchanges with farmers, for the collection of quantitative or qualitative information related to the project progress.

4.1. Animal management

Mitigation strategies concerning a better flock management show a very different GHG reduction potential:

Table 1: Animal management GHG reduction potential

Animal management			
Mitigation actions	% reduction of total kg CH4 emitted ($kgCO_2eq.*year^{-1}$)	% reduction of total kg N2O emitted ($kgCO_2eq.*year^{-1}$)	% reduction of total kg CO2 emitted ($kgCO_2eq.*year^{-1}$)
Increase of reproductive efficiency (Sementusa protocol® application)	22%	23%	22%
Increase of production efficiency	3%	3%	3%

Actions aimed at increasing the reproductive efficiency show a reduction potential of the GHG emitted in the farms over 20%, that means that the application of a "Sementusa" type protocol can lead to a high decrease of the carbon footprint of the farms in which is implemented.

A lower carbon footprint potential reduction is achievable with strategies that increase the production efficiency of the flock. The percentage calculated is around 3% of reduction considering the emissions of CH_4, N_2O and CO_2.

4.2. Animal feed production

The following table show the GHG reduction potential of the mitigation actions related to animal feed production:

Table 2: Animal feed production GHG reduction potential

Animal feed production			
Mitigation actions	% reduction of total kg CH4 emitted (kgCO2eq.*year^{-1})	% reduction of total kg N2O emitted (kgCO2eq*year^{-1})	% reduction of total kg CO2 emitted (kgCO2eq*year^{-1})
Increase of self-producted animal feed	2%	2%	9%
Increase of legume forages and reduction of protein concentrates	1%	1%	1%
Use of feed blocks as integration for low quality forages	0%	4%	1%
Early harvest and/or hay wrapping	1%	1%	9%

The increment of on-farm feed production led to a 9% reduction of CO_2 emitted, related to the less amount of off-farm forages and concentrates purchased by the farmer. CH_4 and N_2O emissions fall both of 2%.

The partial substitution of protein concentrates with legume forages show a reduction of GHG emissions of 1% for each climate-altering gas monitored.

The integration of feed blocks in animals diet, to compensate the nutritional deficit of poor forages, did not show any significant variation on CH_4 emissions, while it is registered a 4% reduction in N_2O released and 1% in CO_2 emitted.

Strategies related to innovative haymaking techniques, aimed to improve farm forage quality, have a very little effect on animal emissions, in fact both CH_4 and N_2O show a reduction potential of 1%. A higher value is registered for the CO_2 emissions, reduced of 9%.

4.3. Feed crop cultivation management

GHG reduction potentials caused by the implementation of mitigation strategies concerning the feed crop cultivation management are shown in the table below:

Table 3: Feed crop cultivation management GHG reduction potential

Feed crop cultivation management			
Mitigation actions	% reduction of total kg CH4 emitted (kgCO2eq*year^{-1})	% reduction of total kg N2O emitted (kgCO2eq*year^{-1})	% reduction of total kg CO2 emitted (kgCO2eq*year^{-1})
Conversion from permanent grassland to improved perennial pasture cultivation	0%	-3%	4%
Conversion from natural pasture to improved natural pasture	0%	0%	3%
Low input soil tillage techniques	0%	0%	0%

Data concerning the application of feed crop cultivation management strategies do not register a significant change on animal emissions. Only the amount of N_2O has had an increase of 3% on the conversion from permanent grassland to improved perennial pasture cultivation.

A decrease of 4% CO_2 emissions is calculated for the conversion from permanent grassland to improved perennial pasture, that is due to a lower fuel consumption utilized during land cultivation. Conversion from natural pasture to improved natural pasture provide a reduction of 3% CO_2 emissions as environmental benefit.

The adoption of low input soil tillage techniques does not have any effect on the carbon footprint of the milk.

4.4. Carbon sequestration

The implementation of mitigation strategies concerning the feed crop cultivation management has a positive effect on soil carbon storage capacity due to a less soil exploitation.

The improvement on carbon sequestration value between the pre and the post intervention situation, considering same portion of area, is estimated as shown on the following table:

Table 4: Feed crop cultivation management carbon sequestration percentage improvement potential

Carbon sequestration	
Mitigation actions	%
Conversion from permanent grassland to improved perennial pasture cultivation	+108%
Conversion from natural pasture to improved natural pasture	+125%

5. Project Impacts on The Sardinian Dairy Supply Chain

The results obtained from the implementation of the mitigation actions planned in SheepToShip LIFE project, measured in the demonstrative farms, is applied in an estimate involving Sardinian farms which shown interest in the application of the eco-innovative strategies proposed by the project.

A hypothesis is made to estimate the number of farms interested in the project method, reached throughout the communication and dissemination strategies implemented by SheepToShip LIFE and the involved farmers feedback, which intend to adopt low input production techniques in their own farm.

It is supposed that farms interested in the eco-innovative strategies proposed have similar hotspots to the demonstrative ones selected, so there is made an estimate to create few clusters characterized by the adoption of the same mitigation strategies.

The environmental effects due to the application of eco-innovative techniques, studied in for each farm selected, will be applied for every cluster defined, estimating the environmental impact of the project on the Sardinian dairy supply chain.

5.1. Sardinian dairy supply chain

Sheep milk production in Sardinia is about 260,000 t $year^{-1}$ for a number of farms located in the island equal to 12.669 (ISTAT, 2010), that means each farm has a medium production of 20,6 t milk every year.

From the final LCA relation of SheepToShip LIFE project it is calculated the value 4,77 $kgCO_2eq$. as a carbon footprint average of the 18 farms studied with the LCA analysis, for every kg of normalized milk produced. It is also calculated that 60% of the total CF is due to methane emissions while 8% is caused by N_2O emissions. As reported in Atzori et al. (2017) scientific paper, CO_2 emissions were considered equal to around 12% of the total Carbon Footprint. Cseq value was calculated considering data collected on the 18 Sardinian farms selected by the project, further details are available at the report on soil C estimate published on the sheeptoship.eu website.

In the table below a representation of the data described is shown:

Table 5: Environmental data of Sardinia dairy supply chain

Sardinian dairy supply chain		
	Unit	Value
Milk produced	t	260.779
Farms	n.	12.669
Carbon Footprint	tCO2eq.	1.243.916
CH4 emitted	tCO2eq.	746.349
N2O emitted	tCO2eq.	99.513
CO2 emitted	tCO2eq.	149.270
Cseq	$kgCO2eq*ha^{-1}$	871,5
Milk produced/farm	t	20,6

5.2. Mitigation effects on the Sardinian dairy supply chain

It is supposed that, at the project ending, 7% of the total Sardinian farmers were reached by the communication and dissemination strategies implemented by SheepToShip LIFE and persuaded by the involved farmers feedback in applying the eco-innovative techniques proposed in their own farm. It is hypothesized that their interest about mitigation strategies is divided as shown in the following table:

Table 6:Farms interested in mitigation strategies application

Farms interested in mitigation strategies application

	Number	Carbon Footprint (tCO2 eq.)
Farms (7% of the total)	887	62.196
Farms interested in the increase of reproductive efficiency (20%)	177	12.439
Farms interested in the increase of production efficiency (15%)	133	9.329
Farms interested in the increase of self-producted animal feed (10%)	89	6.220
Farms interested in the increase of legume forages and reduction of protein concentrates (5%)	44	3.110
Farms interested in the use of feed blocks as integration (2%)	18	1.244
Farms interested in early harvest and/or hay wrapping (15%)	133	9.329
Farms interested in conversion from permanent grassland to improved perennial pasture cultivation (20%)	177	12.439
Farms interested in conversion from natural pasture to improved natural pasture (13%)	115	8.085
Farms interested in low input soil tillage techniques (0%)	-	-

The tables below show the pre and post intervention situation for every greenhouse gases monitored in the project on the farms interested in SheepToShip LIFE mitigation techniques:

Table 7: CH4 mitigation potential in Sardinia dairy supply chain

CH4 mitigation potential in Sardinia dairy supply chain

	CH4 emitted pre intervent (tCO2 eq.)	CH4 reduction potential (%)	CH4 emitted post intervent (tCO2 eq.)	CH4 emissions saved (tCO2 eq.)
Farms (7% of the total)	52.244	-	49.521	2.724
Farms interested in the increase of reproductive efficiency (20%)	10.449	22%	8.178	2.270
Farms interested in the increase of production efficiency (15%)	7.837	3%	7.575	261
Farms interested in the increase of self-producted animal feed (10%)	5.224	2%	5.134	91
Farms interested in the increase of legume forages and reduction of protein concentrates (5%)	2.612	1%	2.594	18
Farms interested in the use of feed blocks as integration (2%)	1.045	0%	1.041	4
Farms interested in early harvest and/or hay wrapping (15%)	7.837	1%	7.741	95
Farms interested in conversion from permanent grassland to improved perennial pasture cultivation (20%)	10.449	0%	10.476	- 27
Farms interested in conversion from natural pasture to improved natural pasture (13%)	6.792	0%	6.781	11

Table 8: N2O mitigation potential in Sardinia dairy supply chain

N2O mitigation potential in Sardinia dairy supply chain				
	N2O emitted pre intervent (tCO2 eq.)	N2O reduction potential (%)	N2O emitted post intervent (tCO2 eq.)	N2O emissions saved (tCO2 eq.)
Farms (7% of the total)	6.966	-	6.619	347
Farms interested in the increase of reproductive efficiency (20%)	1.393	23%	1.077	316
Farms interested in the increase of production efficiency (15%)	1.045	3%	1.010	35
Farms interested in the increase of self-producted animal feed (10%)	697	2%	684	12
Farms interested in the increase of legume forages and reduction of protein concentrates (5%)	348	1%	346	2
Farms interested in the use of feed blocks as integration (2%)	139	4%	134	5
Farms interested in early harvest and/or hay wrapping (15%)	1.045	1%	1.032	13
Farms interested in conversion from permanent grassland to improved perennial pasture cultivation (20%)	1.393	-3%	1.429	- 35
Farms interested in conversion from natural pasture to improved natural pasture (13%)	906	0%	906	- 1

Table 9: CO2 mitigation potential in Sardinia dairy supply chain

CO2 mitigation potential in Sardinia dairy supply chain				
	CO2 emitted pre intervent (tCO2 eq.)	CO2 reduction potential (%)	CO2 emitted post intervent (tCO2 eq.)	CO2 emissions saved (tCO2 eq.)
Farms (7% of the total)	10.449	-	9.583	866
Farms interested in the increase of reproductive efficiency (20%)	2.090	22%	1.634	456
Farms interested in the increase of production efficiency (15%)	1.567	3%	1.526	42
Farms interested in the increase of self-producted animal feed (10%)	1.045	9%	949	96
Farms interested in the increase of legume forages and reduction of protein concentrates (5%)	522	1%	516	6
Farms interested in the use of feed blocks as integration (2%)	209	1%	206	3
Farms interested in early harvest and/or hay wrapping (15%)	1.567	9%	1.423	144
Farms interested in conversion from permanent grassland to improved perennial pasture cultivation (20%)	2.090	4%	2.007	83
Farms interested in conversion from natural pasture to improved natural pasture (13%)	1.358	3%	1.322	36

Data contained in the tables above show the amount of climate-altering gases saved due to the application of eco-innovative techniques proposed by the project in 7% of the Sardinian farms.

Considering the entire Sardinia supply chain the greenhouses gases potential reduction at the end of the project is displayed below:

Table 10: GHG mitigation potential in Sardinia dairy supply chain

GHG mitigation potential in Sardinia dairy supply chain		
	GHG saved every year (kgCO2eq)	% on the entire Sardinia dairy supply chain
CH4	2.724	0,4%
N2O	347	0,3%
CO2	866	0,2%

5.4. Carbon sequestration improvement

An average of 871,5 $kgCO_2eq*ha^{-1}*year^{-1}$ is calculated on the 18 Sardinian farms selected by the project. The implementation of feed crop cultivation management techniques, resulting in a minor soil exploitation, increase soil carbon storage capacity. Considering 1 ha of soil, improvements on Cseq were estimated as shown in the following table:

Table 11: Feed crop cultivation management carbon sequestration improvement potential

Carbon sequestration improvement potential	
Mitigation actions	Cseq ($kgCO2eq*ha^{-1}*year^{-1}$)
Conversion from permanent grassland to improved perennial pasture cultivation	1812,72
Conversion from natural pasture to improved natural pasture	1960,88

Conclusions

With 7% of the farms applying project mitigation strategies, the entire Sardinia supply chain greenhouses gases potential reduction is estimate in 2.724 $kgCO_2eq$ for methane, 347 $kgCO_2eq$ for N_2O and 866 $kgCO_2$ for carbon dioxide. To increase the percentage of climate-altering gases potential reduction is important that the number of farmers who intend to adopt mitigation strategies in their activities grow beyond the end of the project, so that a minor quantity of greenhouse gases emissions would be released in the atmosphere.

The combination of more mitigation strategies in a single farm could lead to a lower amount of CO_2 eq. emissions but further testes had to be done to acquire data on this possibility.

Feed crop cultivation management measures application resulted in a carbon sequestration value improvement potential. Considering 1 ha, conversion from permanent grassland to improved perennial pasture cultivation and conversion from natural pasture to improved natural pasture increase Cseq value of, respectively, 108% and 125%

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