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C.3 Demonstrative sheep farms

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Executive summary

This document concerns the description of demonstration actions and monitoring activities carried out on model farms, with the objective to evaluate the effect of these actions in the environmental, agronomic and economic terms.

For each model farm is reported: i) a description table with the main characteristics of the production system; ii) an action plan table with the hotspots to improve the productive system efficiency, the farmer perception on the identified hotspots, the actions planned in each farm; iii) a mitigation action table where the action is described and activities are reported and, finally iv) a table which summarizes the measured/estimated technical results of the action, and the preliminary assessment of its impact on the farm carbon footprint and cash flow. Finally, as side-product of the demonstration activities results on soil and feedstuff analysis from samples gathered in the model farms are tabled and briefly commented.

Summary

1. Introduction

This report summarizes the activities undertaken within the C.3 "Model farms" implementation action and their preliminary results. This action has the main objective of demonstrating at farm scale mitigation strategies/techniques putatively able to reduce sheep farm Global Warming Potential (GWP, expressed in terms of kg CO_2/Functional Unit) but also to maintain or increase the farm return, having no negative implications on animal welfare and product quality.

To this end, the literature was investigated to review the main mitigation techniques in order to select a portfolio of actions which were expected to broadly fit the sheep dairy system of Sardinia. The twenty sample farms surveyed in the project under the action C.1 "LCA studies" were subjected to critical analysis to identify environmental hotspots. Among these, originally ten farms (now 11), were selected and considered as model farms in order to implement demonstrative actions.

The location of model farms is shown on the Sardinian map in Figure 1.

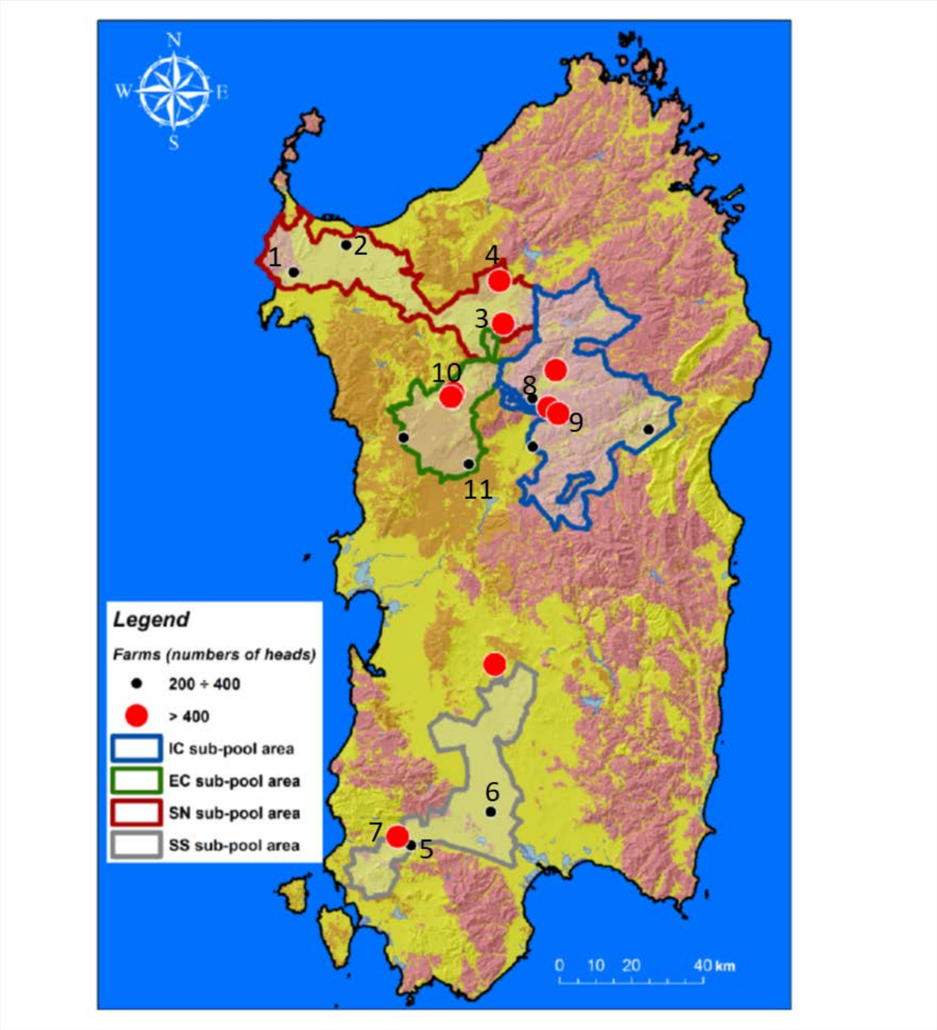


Figure 1. Map of the model farms.

This selection was made in a way to sample the different clusters of farms featured by homogenous soil-climate and the sub-cluster criteria previously identified (flock size and stocking rate). Among candidate farms, the ultimate choice criterium was farmers' availability to undertake the action plan, including at least one mitigation action.
Then, for each model farm was defined: i) an action plan characterized by specific agronomic and livestock interventions for the identified environmental hotspots; ii) a monitoring plan to verify different environmental, agronomic and livestock parameters.
Finally, for some of the actions, monitoring data, consolidated by scientific and grey literature, were been used to launch a preliminary modelling of ecol-econ response of the implemented actions. These data are summarized in the end of the following action forms.

1.1. Action plan

Mitigation actions or strategies entails a vast array of techniques/strategies which impact on several facets.
They can be primarilty classified on the basis of the targeted hotspot:

A. Animal management;
B. Animal feed production;
C. Feed crop cultivation management;
D. Energy consumption.

A. Animal management
The intervention focused on sheep management started in 2018, while targeting the improvement of hay quality in years 2019-2020. The implemented action was the use of feedblocks rich in energy and fermentable protein and feedblocks enriched with minerals during summer-autumn period to improve the digestibility of diets of pregnant sheep based on hay and cereal stubble of poor quality, as confirmed by feedstuff analysis.

Other livestock-based interventions regarded the monitoring of individual milk yield to favour a more accurate culling of low yielding ewes and, in association with the body condition scoring, to allow the grouping of lactating ewes according to their performance in order to better target feeding management.
Moreover, in order to improve flock fertility, enhance productivity and animal welfare a collaboration with SEMENTUSA association (a national association of veterinary surgeons) has been recently undertaken. In fact, flock fertility is considered as a good indicator of the sheep and farm efficiency. SEMENTUSA association has developed a protocol based on the use of an APP which can helps to improve the reproductive efficiency of flocks, monitoring and driving factors such as healthiness of rams, ewe: ram ratio, monitoring of heats and pregnancy, BCS and nutrition at mating and during pregnancy up to lambing.

B. Animal feed production
The agronomic interventions aimed at increasing the production of animal feed on farm were firstly focused on the introduction of perennial pastures as replacer of annual forage crops.
Most sheep farmers, particularly those located in lowlands, devote a large share of their land to annual forage crops, which are established every year after the breaking rains. This increases

the labour requirements for cultivation in a period when most lambings are concentrated, impairs the accuracy of cultivation operation and the care for the peri-parturient sheep.
The partial replacement of these annual crops with perennial artificial pasture based on self-seeding legumes or sulla can: improve the quality of herbage on offer in spring, increase the biomass on offer in autumn, replenish soil organic matter, contrast soil erosion and overall reduce the annual amount of fuel used for pasture establishment and management.
Another important mitigation action envisaged and implemented was aimed at improving the quality of conserved forages. In fact, as shown in the supplementary table 3, the hay produced in sheep farm has often a very high level of fiber and poor protein content, both concurring to depreciate its nutritive value. This depends on the erratic weather pattern but also the traditional harvesting technique, which implies a long suncuring of the cut herbage and quite a lot of operations which can increase the lost of leaves and, hence of nutrive value. To tackle these shortcomings, the intervention on haymaking was oriented on the identification of the best cutting temporal windows for hay production and the production of alternative hays (wrapped bale silage) in order to: increase the quality of on-farm produced forages and to preserve them when adverse weather conditions makes it difficult to produce hay.

C. Feed crop cultivation management
To tackle the high cultivation cost of annual forage crops and cereals, related to high labour intensity and fuel consumption, the implementation of conservative cultivation techniques such as direct seeding (sod seeding) and minimum tillage has been introduced in some model farms in order to demonstrate their benefits as compared to coventional cultivation (ploughing and harrowing for seed-bed preparation).

D. Energy consupmtion.
Although some actions where envisaged (use of more sustainable energy supply, plant of a solar photovoltaic system, use of inverters, etc.), due to the relevant costs to acquire the correlated capital goods, just one action is ongoing in this hotspot class (use of an inverter).
A synopsis of the actions implemented is in table 1.

Table 1 – Synopsis of mitigation actions planned or implementedon farm

Action class/no.	Name of mitigation action	Model farms where the action is planned/implemented
A1	Increase of reproduction efficiency by the implementation of a **"Sementusa-like" protocol**	5, 7, 8 and 10
A2	Increase of sheep milk productivity by a better culling technique on the basis of **milk recording service (A2a**) or use of **flowmeters (A2b)**	5
A3	Increase of diet digestibility in sheep fed low quality hays or cereal stubbles by the use of **feedblocks (A3a)** or **targeted supplementation (A3b) in late spring**	5 and 10
B1	Increase of feed self-sufficiency and reduction of pasture establishment CF impact by replacing annual forage crops **(B1a)** and natural pasture **(B1b)** with **improved pastures** based on self-seeding species	1, 2, 3, 5, 6, 7, 8, 11
B2	Increase of feed self-sufficiency and reduction of pasture establishment CF impact by replacing annual forage crops with a **short-lived perennial legume** (**sulla**)	1, 5, 7
B3	Improvement of conserved forage digestibility by **early cutting of herbage (B3a)** or **haylage wrapped bale** production **(B3b)**	4
C1	Conservative cultivation of forages and cereals by **direct seeding (C1a)** or **minimum tillage (C1b)**	5, 7
D1	Increase of **sustainability of electric energy power** (self-production or selection of more sustainable providers) or **saving of electric energy** (use of inverters)	4

1.1.1 Methodology

During the implementation of mitigation actions, data were collected to measure as accurately as possible the effects of each action. For agronomic actions, soils were sampled and biomass production and botanic composition was assessed by cutting quadrats at ground level outside and inside exclosure cages. Herbage samples were also gathered, mimicking sheep grazing behavior (hand-plucked samples) in order to assess pasture chemical composition (nutrients, macro- and micro-minerals). Also conserved forages and concentrates used in each farm were sampled at least once in year 2018-2019.

Data on animals were also measured, with reference to body condition score and milk yield in some of the model farms.

The data gathered in year 2018-2019, combined with data from previous surveys and experiments were used to launch a preliminary evaluation of the environmental and economic implications of some actions.

For the environmental impact evaluation, comparative LCA was applied, using the methodology described in detail in C.1 “LCA studies” report. This process was undertaken twice: pre and post-mitigation in order to evaluate the estimated GHG abatement in terms of two functional units (FUs): kg of Fat and Protein Corrected Milk (FPCM) or ha of Utilised Agricultural Area (UAA).

As for the economic assessment, the preliminary evaluation was based on cash flow data, using as index the difference between total income and variable (out-of-pocket money) costs pre and post mitigation. Most of these costs are directly related to feeding (feeding costs) which represent the major cost source in sheep farms (Idda et al., 2010).

In some cases, different levels of mitigation were compared (L1, L2) where levels could be either:

- Expected input level: e.g. area invested by the action for agronomic interventions;
- Expected output related to different intensity of intervention.

1.2 Monitoring plan

The monitoring plan included different field activities needed for data and sample collection. This monitoring, which is currently ongoing is aimed at evaluating:

- the annual variability of cultivation techniques, animal management and performance which can help to generalize the survey outcome (e.g. the LCA outcome);
- the carry-over effects of some of the mitigation actions implemented so far;
- the impact of ongoing mitigation action.

To this end, agronomic monitoring entails biomass assessment and sampling during pasture growth season. The monitoring of livestock parameters includes the gathering of key management data (data on reproductive parameters, milk performance and data on flock feeding) and occasionally, sample of sheep milk, grazed herbage and supplements. All samples are processed and sent to the laboratories for the planned determinations.

Finally, the monitoring of environmental parameters consisted of the insects collection in the field, ants in particular, used as land use environmental bio-indicators.

Further data monitoring, e.g. energy and water consumption are under review to be implemented in the next year.

2. Implemented actions

NORTH AREA

Farm 1 – Arca Gavino

Farm characteristics		Farm 1 - Arca
Geographical area		North
Pedologic substrate		Alluvial
Altitude	m a.s.l.	50
Total Agricultural Area (TAA)	ha	74.7
Utilized Agricultural Area (UAA)	ha	71.7
Natural pasture area	%	23.7
Annual forage crops	%	76.3
Heads (number of mature ewes)	N	375.0
Stocking rate	head ha^{-1}	5.2
Fertility of mature ewe	%	92.3
Neonatal lamb mortality (1)	%	5.3
Milk total annual production	kg FPCM	72,649
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	193.7
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.94
Feed Self-Sufficiency	% (Dry Matter)	70.6
Work units	N	1
Electricity consumption	kWh 100 kg $FPCM^{-1}$	25.16
Diesel consumption	Lt 100 kg $FPCM^{-1}$	5.98

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
High percentage of cultivated land with annual forage crops that determines high working costs (in terms of time and money) and high diesel consumption	Farmer aware of the forage system's weakness: need of improving his knowledge for transforming annual crop into perennial artificial pastures	**B1a.** Cultivation of artificial pastures on area previously occupied by annual crops, using a mixture of perennial and annual self-reseeding grasses and legume species, suitable for the site's pedoclimatic conditions. Adoption of specific agricultural techniques to allow the artificial pasture establishment and persistence **B2.** Cultivation of Sulla (Hedysarum coronarium) on area previously occupied by annual crops. Adoption of specific agricultural techniques to allow the Sulla biennial crop establishment
High electricity consumption per kg FPCM	Farmer aware of the high electricity consumption: lack of intervention due to organizational difficulties and little time available	**D**. Electrical system audit needed to measure possible energy waste and to improve the plant efficiency (preliminary plan)

IMPLEMENTED ACTION 1.B1 - PARTNER RESPONSIBLE CNR-IBE / CNR-ISPAAM

NAME OF THE IMPLEMENTED MITIGATION ACTION: REPLACEMENT OF AN ANNUAL FORAGE CROP BY A PERMANENT PASTURE UNDER IRRIGATION

Period	From October 2018 (modelization refer to year 2016/2017)
Critical issues detected	High percentage of area yearly tilled, which determines a high cultivation intensity. This entails high consumption of fuel and other energy inputs, as well as a heavy workload, both in economic and organizational terms.
Objective of the action	Reduction of the economic, working and organizational burdens deriving from the frequent cultivation of soil for forage production, and relative improvement of environmental performance (reduction of GHG emissions, reduction of soil erosion, improvement of the C stock in the soil)
Description of the action	Revision of annual cultivation plan, with the replacement of a part of the area usually devoted to annual crops with improved perennial pastures, consisting of mixtures of perennial and self-seeding leguminous and graminaceous species. In detail, we proceed with the minimum tillage and sowing of the mixture by a seed broadcaster. Pasture management involves rotational grazing and 1-3 flail mowing to control weeds after grazing. Grazing season stopped at flowering to favour re-seeding, which is fundamental especially the first year to ensure the resilience of the pasture.
Expected results	Reduction of fodder self-production costs and relative reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment of annual forage crops; ii) Reduction of working costs and working times necessary for fodder production, with relative improvement of work organization and planning in the autumn; iii) Reduction of GHG emissions due to less use of energy inputs; iv) Reduction of soil erosion due to the lower intensity of the work involved; v) Improvement of soil fertility with an increase in the stock of organic C, favored by slow mineralization processes.
	Farm visits devoted to the action
Date	Activity
June 2018	Preliminary assessment of ecological hotspots
October 11, 2018	Soil sampling
October 15, 2018	Ploughing
November 13, 2018	Harrowing
November 14, 2018	Sowing of perennial pasture mixture
November 17, 2018	Rolling
January 14, 2019	Assessment of the establishment of sown species
February 5, 2019	Exclosure cage setting
February 28, 2019	Herbage mass sampling

March 8, 2019	Herbage mass sampling
March 27, 2019	Herbage mass sampling
April 16, 2019	Herbage mass sampling
May 10, 2019	Installation of traps for insect samplings
May 17, 2019	Insect samplings
June 3, 2019	Herbage mass sampling
June 6, 2019	Installation of traps for insect samplings
June 12, 2019	Insect samplings
July 3, 2019	Monitoring visit
July 8, 2019	Flail mowing of pasture
Julay 30, 2019	Monitoring visit
August, 30 2019	Monitoring visit
September 10, 2019	Herbage mass sampling
October 15, 2019	Monitoring visit
November 20, 2019	Monitoring visit
December 27, 2019	Herbage mass sampling
January 15, 2020	Herbage mass sampling
February 20, 2020	Herbage mass sampling
February 25, 2020	Flail mowing of pasture
March 29, 2020	Herbage mass sampling
April 22, 2020	Herbage mass sampling
May 10, 2020	Herbage mass sampling
May 17, 2020	Flail mowing of pasture

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	**Irrigated forage crop (mixture grass-legumes):** - Estimated equivalent biomass production: 5.13 t DM ha^{-1} - Fertilizer consumption: 39 kg N ha^{-1} - Diesel consumption: 62 liters ha^{-1} - Irrigation water consumption: 829 m3 ha^{-1} - Consumption electric energy (for irrigation): 683 kWh ha^{-1} - working hours: 8.48 h ha^{-1} **- Improved pasture (average annual values from 3 years of pasture are considered):** - Estimated equivalent biomass production: 4.58 t DM ha^{-1} - Fertilizer consumption: 0 kg N ha^{-1} - Diesel consumption: 37 Liters ha^{-1} - Irrigation water consumption: 332 m^3 ha^{-1} - Consumption electric energy (for irrigation): 273 kWh ha^{-1} - working hours: 4.46 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	Level 1 (system boundary represented by the single 3.65 ha plot) a) **Climate Change** (FU: t DM biomass equivalent) - **forage crop**: 236 kg $CO_{2\text{-eq}}$ per t DM - **improved pasture**: 58 kg $CO_{2\text{-eq}}$ per t DM b) Climate Change (FU: ha of UAA) - forage crop: 1209 kg CO $_{2\text{-eq}}$ per ha - improved pasture: 298 kg CO2$_{\text{-eq}}$ per ha Level 2 (border of the system represented by the entire production system, with replacement of 11.45 ha (irrigable area) of grass with improved pasture) c) Climate Change (FU: 1 kg FPCM) - basic scenario (forage crop based on grass only): 3.94 kg $CO_{2\text{-eq}}$ per kg FPCM - mitigation based on improved pasture: 3.89 kg $CO_{2\text{-eq}}$ per kg FPCM.
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	- Forage crop: € 58 t DM^{-1} equivalent biomass - Improved pasture: 31 € t DM^{-1} equivalent biomass - **Economic savings**: improved pasture vs forage crop (per t SS of biomass equivalent) a) 27 € t DM^{-1} b) 46% t DM^{-1} - **Improved pasture area necessary to equal the yield of the grass**: 1.12 ha - **Labor savings** Improved pasture vs forage crop (per ha equivalent UAA) a) 3.50 h ha^{-1} b) 41% ha^{-1}

Pasture improvements in Arca G. farm

Implemented action 1.B2 - Partner responsible: **CNR-IBE / CNR-ISPAAM**

Name of the implemented mitigation action: Replacement of an irrigated forage crop with sulla (short-lived perennial legume)

Period	From October 2019 (modelled impact refers to year 2016/2017)
Critical issues detected	High intensity of annual processing of company surfaces, with consequent high fuel consumption and onerous workload, both in economic and organizational terms.
Objective of the action	Reduction of work and organizational costs deriving from the frequent soil tillage for forage production, and related improvement of environmental performance (reduction of GHG emissions). Improvement of the quality of fodder biomass and increase of the milk yield per lactating ewe.
Description of the action	Revision of the cropping plan, with the replacement of a part of the areas invested in grass with a biennial plant. In detail, the soil is tilled, the seed is inoculated and then sown. Crop management involves rotational grazing associated with flail mowing (from 1 to 2 operations per year), with the aim of controlling weeds.
Expected results	i) Reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment and management of annual forage crops; ii) Reduction of workloads and work times necessary for fodder production, with relative improvement of the organization and planning of farm activities in the autumn; iii) Improvement of the quality of the self-produced forage biomass and of the milk yields per lactating ewe; iii) Reduction of GHG emissions due to less use of energy inputs.
	Farm visits devoted to the action
Date	Activity
June 2018	Preliminary assessment of hotspots i
October 11, 2018	Soil sampling
October 20, 2019	Ploughing
October 21, 2019	Harrowing
October 22, 2019	Inoculum preparation and treatment of the seed
October 23, 2019	Sowing and rolling
December 15, 2019	Monitoring visit
February 9, 2020	Flail mowing
February 27, 2020	Monitoring visit
April 26, 2020	Flail mowing

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	**Irrigated forage crop (berseem clover):** - Estimated equivalent biomass production: 5.13 t DM ha^{-1} - Fertilizer consumption: 26 kg N ha^{-1} - Diesel consumption: 62 liters ha^{-1} - Irrigation water consumption: 442 m^3 ha^{-1} - Consumption electric energy (for irrigation): 364 kWh ha^{-1} - working hours: 8.20 h ha^{-1} - **Sulla (average annual values from 2 years of sulla are considered):** - Estimated equivalent biomass production: 3.95 t DM ha^{-1} - Fertilizer consumption: 9 kg N ha^{-1} , 23 kg P_2O_5 ha^{-1} - Diesel consumption: 45 Liters ha^{-1} - Irrigation water consumption: 442 m^3 ha^{-1} - Consumption electric energy (for irrigation): 364 kWh ha^{-1} - working hours: 6.67 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	Data are not yet available
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Forage crop: 42.1 € t DM^{-1} equivalent biomass Sulla: 39.7 € t DM^{-1} equivalent biomass - **Economic savings**: Sulla vs Forage crop (per t DM equivalent biomass) a) 2.4 € t DM^{-1} b) 6% t DM^{-1} **- Sulla area necessary to equal the yield of forage crop**: 1.30 ha - **Labor savings** Sulla vs Forage crop (per ha equivalent UAA) -a) 0.45 h ha^{-1} b) 6% ha^{-1}

FARM 2 – RIU MICHELE & DOMENICO

Farm characteristics		Farm 2 - Riu
Geographical area		North
Pedologic substrate		Alluvial
Altitude	m a.s.l.	464
Total Agricultural Area (TAA)	ha	51.8
Utilized Agricultural Area (UAA)	ha	51.8
Natural pasture area	%	49.8
Annual forage crops	%	50.2
Heads (number of mature ewes)	N	248
Stocking rate	head ha^{-1}	4.8
Fertility of mature ewe	%	87.1
Neonatal lamb mortality [(1)]	%	8.3
Milk total annual production	kg FPCM	38,017
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	153.3
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.89
Feed Self-Sufficiency	% (Dry Matter)	75.3
Work units	N	2
Electricity consumption	kWh 100 kg $FPCM^{-1}$	11.7
Diesel consumption	Lt 100 kg $FPCM^{-1}$	13.9

[(1)] (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low feed-self sufficiency	The farmers are aware of the relatively low forage productivity of their land. They have considerably improved the quality of their pastureland, by establishing self-reseeding legumes and grasses adapted to farm soil and topography. They aim to pursue this improvement on some paddocks, recently used for annual crops. The farmers have a clear propensity to innovation	**B1a.** 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. Adoption of specific agricultural techniques to allow the artificial pasture establishment and persistence in order to reduce the soil tillage interventions and hence the carbon footprint
High energy consumption	The farmers are aware of it and thus they have already planned to use a photovoltaic system to reduce the cost related to milk refrigeration and processing. They might move to machine milking if the cost of it is reduced	
Low level of production per head	The farmers are aware of this weakness. They prefer a moderate level of production but with high concentration of protein and casein to maximize on-farm cheese production	
Low fertility of ewe-lambs	The farmers are aware of the problem and they have already counteracted it by a vaccination program	

Implemented action 2.B1a - Partner responsible CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of an annual forage crop by a permanent pasture…………………………..

Period	From October 2018 (modelization refer to year 2016/2017)
Objective of the action	Reduction of the economic and labour organizational burdens deriving from the frequent soil tillage for the forage self-production of the herbariums. Productivity increase of the forage system, with improvement of the yield of the sloping plots invested in grass. Improvement of the sustainability and environmental performance of self-produced forage (reduction of GHG emissions, reduction of soil erosion and improvement of the C stock in the soil of the sloping plots)
Description of the action	Replacement of a part of the more sloping areas invested in annual forage crops based on grasses with improved perennial pastures, consisting of mixtures of perennial and self-seeding leguminous and graminaceous species. In detail, we proceeded with the tillage and sowing of the mixture. Pasture management is based on rotational grazing associated with flail mowing (from 1 to 3 operations per year), with the aim of controlling weeds. Pasture grazing is stopped at flowering which is fundamental to ensure the resilience of the pasture, especially the first year.
Expected results	Reduction of fodder self-production costs and relative reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment of annual forage crops; ii) Reduction of working costs and working times necessary for fodder production, with relative improvement of work organization and planning in the autumn; iii) Reduction of GHG emissions due to less use of energy inputs; iv) Reduction of soil erosion due to the lower intensity of the work involved; v) Improvement of soil fertility with an increase in the stock of organic C, favored by slow mineralization processes.
	Farm visits devoted to the action
Date	Activity
June 2018	Preliminary assessment of ecological hotspots
November 10, 2018	Soil sampling
November 12, 2018	Heavy harrowing
November 13, 2018	Light harrowing
November 14, 2018	Sowing by broadcaster
November 17, 2018	Seed covering
January 14, 2019	Assessment of the establishment of sown species
February 19, 2019	Monitoring visit
February 20, 2019	Exclosure cages setting
March 26, 2019	Herbage mass sampling
March 27, 2019	Herbage mass sampling
April 16, 2019	Herbage mass sampling
May 10, 2019	Insect trap setting
May 17, 2019	Insect sampling
June 4, 2019	Herbage mass sampling

June 6, 2019	Insect trap setting
June 12, 2019	Insect sampling
July 3, 2019	Monitoring visit
July 25, 2019	Light harrowing to favour seed cover
September 10, 2019	Herbage mass sampling
October 12, 2019	Herbage mass sampling
December 20, 2019	Monitoring visit
January 12, 2020	Herbage mass sampling
May 25, 2020	Herbage mass sampling

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Pastures improvement in Riu farm

Farm 3 – Manconi Paolo

Farm characteristics		Farm 3 - Manconi
Geographical area		North
Pedologic substrate		Alluvial
Altitude	m a.s.l.	240
Total Agricultural Area (TAA)	ha	132.4
Utilized Agricultural Area (UAA)	ha	126.0
Natural pasture area	%	85.3
Annual forage crops	%	14.7
Heads (number of mature ewes)	N	420
Stocking rate	head ha^{-1}	3.3
Fertility of mature ewe	%	93.6
Neonatal lamb mortality (1)	%	2.3
Milk total annual production	kg FPCM	60,961
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	145.1
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	1.43
Feed Self-Sufficiency	% (Dry Matter)	64.9
Work units	N	1
Electricity consumption	kWh 100 kg $FPCM^{-1}$	14.0
Diesel consumption	Lt 100 kg $FPCM^{-1}$	5.7

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low feed self-sufficiency, low forage quality and productivity of natural pastures and critical presence of weeds	The farmer is aware of the problem and they are inclined to innovative interventions to improve the productive system efficiency; they need to be driven in this intervention plans	**B1b**: Pasture improvement interventions through weed control (mowing and mulching) and overseeding of perennial and annual self-reseeding grass-legume mixture
Low milk persistence during mid lactation	The farmer is aware of the problem and he is interested to tackle it by an innovative intervention	**A3b:** targeted supplementation in late spring. The action has been recently implemented. It is based in the use of a supplement aimed at increasing milk persistence, through an increase of diet digestibility, with putative positive implications on reproduction efficiency. This would entail a reduction of flock emission intensity
	Positive predisposition to data collection in order to know which are the inefficiency and try to improve it (especially from the farmer's daughter)	*Monitoring activity* Data collection regarding the time interval from October 1st 2018 to September 30st 2019 in order to implement a second LCA analysis

Implemented action 3.B1b - Partner responsible: CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of a natural pasture with an improved perennial pasture

Period	From October 2018 (modelization refer to year 2016/2017)
Critical issues detected	Limited farm fodder productivity. In particular, the forage produced by some plots intended for natural pasture is limited and of mediocre quality. In addition, the presence of weeds such as thistle in these plots negatively affects the production capacity of natural pastures.
Objective of the action	Increase in productivity of natural pastures, with the improvement of forage biomass produced and reduction of the presence of weeds. Improvement of the environmental performance of self-produced forage, with the reduction of GHG emissions in relation to the improvement of the digestibility of the forage biomass offered.
Description of the action	Improvement of natural pastures, with practices of weed control and over-seeding of perennial and self-seeding legumes-grass mixture. In detail, we proceed with flail mowing major weeds (thistles) followed by a minimum tillage (harrowing) and sowing of the mixture. Pasture management is rotational with from 1 to 3 flail mowings per year with the aim to control weeds. Pasture grazing is stopped at flowering to ensure the resilience of the pasture, especially the first year.
Expected results	i) Improvement of the quality of self-produced biomass; ii) Greater productivity of pasture and consequent greater capacity for self-supply; iii) Reduction of GHG emissions in relation to greater digestibility of forage;
	Farm visits devoted to the action
Date	Activity
June 2018	Preliminary assessment of ecological hotspots
October 25, 2018	Soil sampling
October 30, 2018	Flail mowing
November 16, 2018	Harrowing
November 17, 2018	Sowing by broadcaster
January 15, 2019	Assessment of the establishment of sown species
February 4, 2019	Monitoring visit
February 20, 2019	Exclosure cage setting
March 17, 2019	Herbage mass sampling
March 30, 2019	Herbage mass sampling
April 23, 2019	Herbage mass sampling
May 10, 2019	Setting of traps for insect sampling
May 17, 2019	Insect sampling
June 5, 2019	Herbage mass sampling
June 6, 2019	Setting of traps for insect sampling
June 12, 2019	Insect sampling
July 3, 2019	Monitoring visit
September 10, 2019	Herbage mass sampling

September 30, 2019	Flail mowing of weeds
November 20, 2019	Herbage mass sampling
December 20, 2019	Monitoring visit
January 12, 2020	Herbage mass sampling
April 27, 2020	Herbage mass sampling
May 25, 2020	Herbage mass sampling

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Implemented action 3.A3 - Partner responsible: UNISS-Department of Agricultural Sciences

Name of the implemented mitigation action: A2 Improving production efficiency through feeding

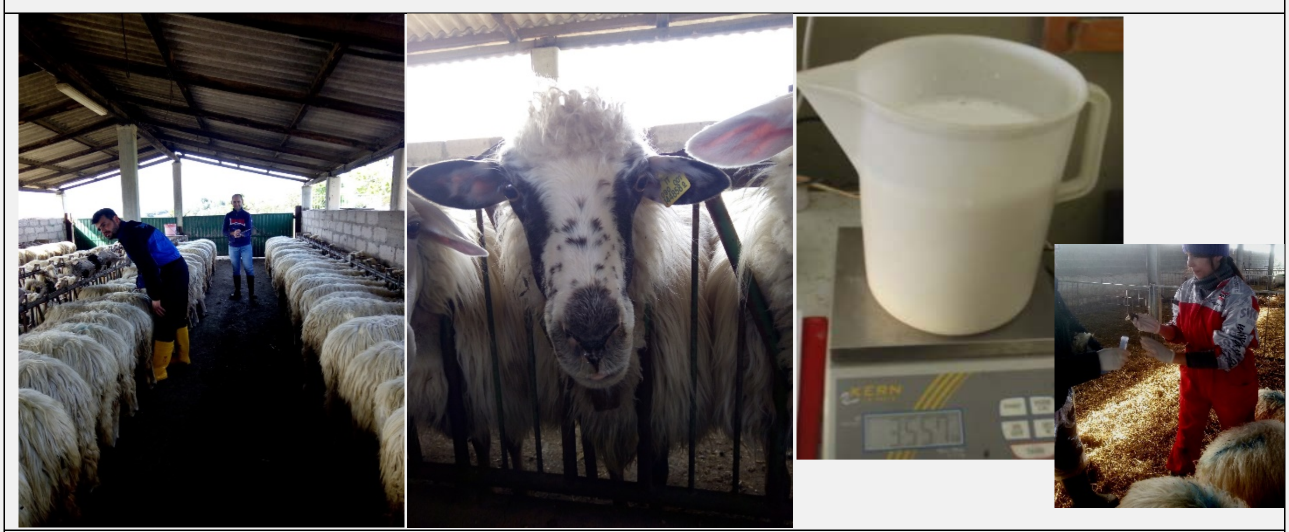
Farm	Manconi - Nord
Period	May to November 2020
Criticity	Nutritional magement of the flock in end of lactation and mating
Objective of the action	Improve milk production in late lactation to improve production and reproductive efficiency
Description of the action	Use of feed supplementation in barn in addition to grazing. The objective of this action was to improve the nutritional level of the flock when a qualitative decay of the fibre and protein of the pastures is observed. From the productive point of view: The nutritional improvement should support the activity of the mammary gland by contrasting apoptosis and senescence of cells, allowing a greater persistence of lactation. From the reproductive point of view: nutritional improvement should have an effect similar to a short-term flushing. The integration has started 10 days before the start of matings. In particular, supplementation should favour the ewe physiological conditions for the resumption of ovarian activity, the evidence of oestrus and the fecundation of the ewes for an improvement in fertility and prolificity From an operational point of view, an additional feed in the dose of 350 grams per head was offered in the late evening to all animals of the lactation group of 390 heads. It should avoid the long fasting between the time of return from the evening grazing until the morning milking supplementation. The feed administered is a dry mix consisting of 50% hay and 50% grain and legume meal, by-products and supplements. The average composition is 15% crude protein, 39% NDF fibre and 15% starch on the dry matter basis. Soybean meal supplementation is under evauation to compensate for the further decrease in protein intake from grazing in the most recent weeks.
Expected results	Improvement in production performance: the supplement provides energy for the production of about 250 grams of milk per head but a lower improvement is expected due to the fact that the energy distribution of the diet in this physiological phase is partially shifted towards the accumulation of body reserves. From the reproductive point of view, an improvement in fertility of 1-3% and a significant increase in prolificness is expected. From a mitigation point of view, an improvement in the efficiency of the herd and an improvement in the digestibility of the diet of about 1-2% is expected, which allows to reduce methane emissions per kg of dry matter ingested.
	Farm visits devoted to the action
Date	Activity
18 May 2020	Feed delivery to the farm
19 May 2020	Starting nutritional integration

20 may	Starting data collection for intake and milk production
29 May 2020	Evaluation of intake and beginning of reproduction activity of the rams
3 June 2020	Evaluation of additionl supply (50 gr capo o protein concentrates)
June2020	Data collection for intake and milk yield
May 2020 – Luglio 2020	check of production and reproduction factors

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Milk production and quality, milked animals, feed effciency. Assessment of fertility performances.
Environmental impact (carbon footprint) pre and post-action deployment	The preliminary estimate of the milk improvement, so far, has given unsatisfactory results. The farm has a very large area available for grazing and carries out only one daily milking. It is assumed that the availability of feed for grazing and the dietary selection of the sheep allowed to meet the nutritional requirements of the udder for the whole production potential. Feed supplementation has so far shown no improvement in feed efficiency. Pre: The farm's pre-intervention carbon footprint was equal to: 4.15 kg CO2 equivalent per kg of milk produced. Post: The improvement in digestibility is expected to have reduced methane emissions by 1% over the reference period, so the impact on emissions on an annual basis is estimated at 4.13 kg of CO_2 equivalent per kg of milk produced.
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Feed consumption has increased by about 350 grams per head per day with a cost increase of about 0.10 €/d per head. Currently, calculations on milk production do not justify the additional cost of the ration considering that a direct break even should imply an increase of production of 125 gr/milk per head. The evaluation of reproductive performance is likely to have positive effects but it is still under evaluation.

Improvement actions in Manconi farm

a) Biomass quantification, measurement of grass height and samples collection of natural pasture, improved pasture and of hay



b) BCS estimation, measurement of milk production, individual milk samples collection and fecael collection

FARM 4 – SOLINAS ANTONIO

Farm characteristics		Farm 4 - Solinas
Geographical area		North
Pedologic substrate		Alluvial
Altitude	m a.s.l.	390
Total Agricultural Area (TAA)	ha	70.3
Utilized Agricultural Area (UAA)	ha	68.0
Natural pasture area	%	0.0
Annual forage crops	%	100.0
Heads (number of mature ewes)	N	500
Stocking rate	head ha^{-1}	7.4
Fertility of mature ewe	%	88.4
Neonatal lamb mortality (1)	%	4.5
Milk total annual production	kg FPCM	78,298
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	156.6
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.76
Feed Self-Sufficiency	% (Dry Matter)	76.4
Work units	N	1
Electricity consumption	kWh 100 kg $FPCM^{-1}$	9.5
Diesel consumption	Lt 100 kg $FPCM^{-1}$	9.9

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low on-farm hay quality	The farmer is aware of the problem and he has a good propensity for change and innovation	**B3.** Better management of haymaking process: identification of the best cutting temporal windows for hay production and production of wrapped bale silage in order to increase on-farm hay quality and preserve it under adverse weather conditions
Low efficiency of energy use	The farmer is aware of the problem	**4.D1.** Reduction of electric energy consumption by the use of an inverter

Implemented action 4.B3a and 4.B3b - Partner responsible: UNISS- Department of Agricultural Sciences

Name of the implemented mitigation action: B6 – Production of early cut hay and wrapped (and chopped) bale silage

Period	Autumn-Winter 2018- Spring 2019 Seasons
Critical issues detected	On-farm low quality forages
Objective of the action	Increase the digestibility of on-farm produced forages and especially the quality of forage (in terms of high CP and low NDF contents)
Description of the action	Use of innovative haymaking tecniques to produce early cut hay and wrapped (and chopped) bale silage. These tecniques are realized anticipating the temporal windows of cutting (optimal phenological stage) and reducing the temporal windows of haymaking (2 days) which preserve forage from adverse weather condition that can occur during traditional haymaking (6-7 days)
Expected results	Improvement of enviromental and productive performance. Specifically, produce more milk, reduce enteric CH_4 per kg of FPCM, reduce the amount of off-farm feeds especially those rich in protein such as alfalfa and soybean meal and thus the emissions linked to them (GHG emissions from off-farm produced feeds)
	Farm visits devoted to the action
Date	Activity
October, 15 2018	Monitoring field. Soil tillage - harrowing operation; soil fertilization; sowing operation; harrowing operation
March, 20 2019	Monitoring activity - analysis of phenological phases of plants
March, 27 2019	Monitoring activity - analysis of phenological phases of plants
April, 16 2019	Monitoring activity - analysis of phenological phases of plants
April, 26 2019	Monitoring activity - analysis of phenological phases of plants
April, 29 2019	Monitoring activity - analysis of phenological phases of plants
May, 2 2019	Production of wrapped and chopped bale silage. Monitoring haymaking operations and samples collection. Physical and biometric analysis; chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content

May, 7 2019	Production of early cut hay. Monitoring activity – biomass sampling; physical and biometric analyses; chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
May, 8 2019	Production of early cut hay. Monitoring activity – 24 hours after cutting: physical, chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
May, 9 2019	1) Production of early cut hay. Monitoring activity – 48 hours after cutting: physical, chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content 2) Production of wrapped and chopped bale silage - Monitoring of silage fermentation (6 days after wrapped bale silage collection): physical and chemical analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
May, 10 2019	Production of early cut hay. Monitoring activity – 72 hours after cutting: physical, chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
May, 11 2019	Production of early cut hay. Field activity - Bailing hay
May, 14 2019	Production of wrapped and chopped bale silage - Monitoring of silage fermentation (11 days after wrapped bale silage collection): physical and chemical analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
May, 22 2019	Production of wrapped and chopped bale silage - Monitoring of silage fermentation (19 days after wrapped bale silage collection): physical and chemical analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
June, 4 2019	Production of wrapped and chopped bale silage - Monitoring of silage fermentation (30 days after wrapped bale silage collection): physical and chemical analyses for the determination of DM, CP, NDF, ADF, ADL and ash content
June, 11 2019	Monitoring activity – hay sampling; physical, chemical and NIRS analyses for the determination of DM, CP, NDF, ADF, ADL and ash content

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Our results showed that high quality forages can be produced and used effectively to totally replace by-products and purchased forages (alfalfa hay) and partially (62%) concentrate rich-proteins
Environmental impact (carbon footprint) pre and post-action deployment	- Production of wrapped and chopped bale silage: 5.04 vs 4.58 kg $CO_{2\,eq}$ kg $FPCM^{-1}$ (pre and post-action deployment, respectively) - Production of early cut hay: 5.04 vs 4.68 kg $CO_{2\,eq}$ kg $FPCM^{-1}$ (pre and post-action deployment, respectively)
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	PRODUCTION OF WRAPPED AND CHOPPED BALE SILAGE - Revenue: 63276.30 Euros (pre and post-action deployment, since milk and meat production were considered constant) - Total Feeding cost: 21293 vs 17279 Euros (pre and post-action deployment, respectively) - Annual Feeding cost per head: 36 vs 29 Euros $head^{-1}$ per $year^{-1}$ (pre and post-action deployment, respectively)

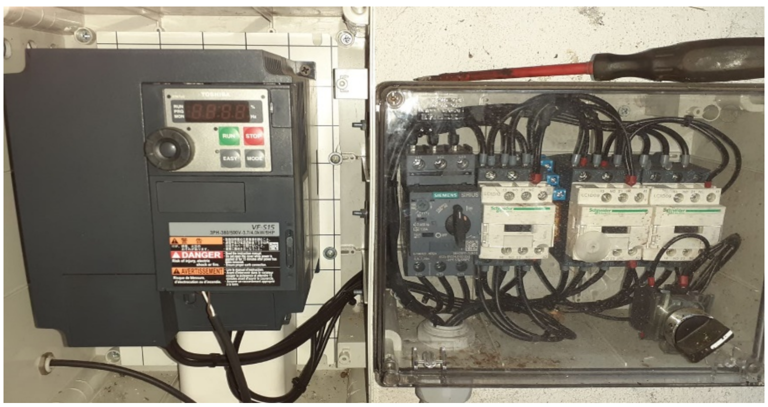
	- Cost required to produce wrapped (and chopped) bale silage 6 Euros/100 kg DM - Ratio between Renvenues and Cost: 2.97 vs 3.36 (pre and post-action deployment, respectively) PRODUCTION OF EARLY CUT HAY - Revenues: 63276.30 Euros (pre and post-action deployment, since milk and meat production were considered constant) - Total Feeding cost: 21293 vs 9460 Euros (pre and post-action deployment, respectively) - Annual Feeding cost per head: 36 vs 16 Euros $head^{-1}$ per $year^{-1}$ (pre and post-action deployment, respectively) - Ratio between Revenues and Cost: 2.97 vs 6.69 (pre and post-action deployment, respectively)

Improvement actions in Solinas farm

Production of wrapped bale silage	Production of hay at its best stage
 	 
a) Grass height and biomass quantification	a) Grass height and biomass quantification
	
b) Cutting	b) Cutting
	
c) Measurement of moisture	c) Measurement of moisture
	
d) Wrapped bale silage production	d) Hay production
   	
e) Chemical and NIRS analyses and monitoring plan	

Implemented action 4.D1 - Partner responsible: Uniss - Department of Agricultural Sciences

Name of mitigation action: Improving energy efficiency in the farm

Period	Lactation 2019-2020
Critical issues detected	High energy consumption for electrical power used in the farm; it has to be noticed that in this famr electricity consumption is not high in terms of intensity or compared to the percentage impact on greenhouse gas emissions but is one of the main items of possible mitigation in the company.
Objective of the action	1) Reducing emissions by reducing the electricity consumption of the milking equipment 2) Reduce greenhouse gas emissions by changing the energetic mix of power sources and thus increasing the share of renewable energy compared to fossil fuels.
Description of the action	**1) Installing an inverter** The technical characteristics of the installed inverter are: Toshiba model VF-S15 which includes the control unit and a display of the operating parameters; it is also equipped with a vacuum sensor capable of detecting minimal fluctuations (even of only 0.1 kPa) ensuring timely intervention of the frequency inverter, to maintain high stability of the vacuum level even in case of simultaneous fall of several milking clusters. The company's milking parlour has 24 stalls with 12 milking clusters.  The inverter has been coupled with the conventional vacuum regulator (by-pass). The technical root of this intervention is to reduce the energy absorption of the vacuum pump, which is one of the main elements of the milking equipment. The purpose of this operation is to increase operational efficiency while reducing energy consumption. The role of the inverter is to modulate the electric engine that drives the pump, in order to vary its rotation speed in relation to the vacuum level that is really necessary in the different phases of the milking routine. The inverter varies the frequency of the alternating current that feeds the motor so that it only delivers the power really needed to maintain the vacuum reserve. In addition to the reduction in electricity consumption, the associated advantages consist of a reduction in plant wear and tear (with a consequent increase in duration and maintenance intervals) and lower noise levels for the benefit of animal welfare and operators. The technical objective is to reduce the useful vacuum reserve for a timely intervention of the vacuum pump aimed at sizing the useful reserve of the system according to the real need for operational vacuum.

	The evaluation of the replacement of the vacuum pump motor (currently 4KW) is in progress because with the availability of the inverter it is possible to obtain the same performance with a motor of smaller size and power reduced by about 25%. 2) **Change of energy provider**: the change of supplier has included the change from ENEL national electrical service to AGN AUTOGAS group which supllies energy mixes as respectively reported in the following table:

Provider	AGN	ENEL SEN
source	mix energetico	mix energetico
Other sources	2.99	4.9
Carbon	12.47	19.99
Renewable energy	40.83	4.0
Natural gas	39.06	64.33
Nuclear	4.11	5.93
Oil products	0,54	0.85

Expected results	1) Improvement of energy performance to reduce milking electricity consumption. Compared to the size of the Solinas barn, it is estimated a level of energy consumption reduction equal to 35% of milking and washing consumption. 2) A reduction in emissions is expected proportional to the change in the energy mix (+36.83% of renewable sources with AGN vs. Enel SEN).
	Farm visits devoted to the action
Date	Activity
5 Luglio 2019	1) Inverter installation and 2) Change of power provider
23 ottobre 2019	Pre-improvement inspection and audit (Mechanical section collaboration)
11 Febbraio 2020	Inspection and evaluation of plant operation
8 Maggio 2020	Energy data collection
4 giugno 2020 (previsto)	Evaluation of vacuum pump engine modification
Luglio 2020	Calculation of environmental improvement 2019-2020 compared to 2017
Novembre 2020 - febbraio 2021	Monitoring
Febbraio 2021	Complete action report

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Energy audit Survey of energy consumption and estimation of working time of the equipment components; A further action is programmed to evaluate the possibility of replacing the milking machine motor as the power currently required is 4 KW whereas with the inverter the power required could be reduced to a 3.0 KW engine. Comparison of the useful vacuum reserve pre and post improvement during the checks of functioning parameters of the milking machine; it will be carried out in collaboration with LAORE technicians.
Environmental impact (carbon footprint) pre and post-action deployment	Pre-intervention environmental impact: - pre: energy consumption of 0.10 KWh per kg of milk produced. - pre: emissions from electricity 0.03 kg of CO_2 eq per kg of milk produced Post-intervention environmental impact: estimated to reduce milking energy consumption by about 35%. - post: energy consumption of 0.08 KWh per kg of milk produced. - post: emissions from electricity 0.028 kg of CO_2 eq per kg of milk produced
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Estimated calculations based on currently collected information. Cost of the inverter 1750,00 euro complete with installation. Estimated duration 10 years (175,00 €uro per year) Estimated annual savings of about €300 for reduced electricity consumption 2) The calculations are still in progress

SOUTH AREA

Farm 5 – Cugusi Alessandro

Farm characteristics		Farm 5 - Cugusi
Geographical area		South
Pedologic substrate		Alluvial
Altitude	m a.s.l.	121
Total Agricultural Area (TAA)	ha	64.2
Utilized Agricultural Area (UAA)	ha	56.8
Natural pasture area	%	11.1
Annual forage crops	%	88.9
Heads (number of mature ewes)	N	303
Stocking rate	head ha^{-1}	5.3
Fertility of mature ewe	%	99.3
Neonatal lamb mortality [(1)]	%	18.3
Milk total annual production	kg FPCM	51,996
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	171.6
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.75
Feed Self-Sufficiency	% (Dry Matter)	79.6
Work units	N	3
Electricity consumption	kWh 100 kg $FPCM^{-1}$	13.3
Diesel consumption	Lt 100 kg $FPCM^{-1}$	11.4

[(1)] (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Poor quality of on-farm made hay	The farmer is fully aware of this problem. This is due to an early decay of hay quality in spring, because of difficulty for grazing management of annual forage crops during autumn-winter. Moreover the farmer, thanks to the fundamental help of the nutritionist of ARA (Regional Breeder Association) compensates for the low quality of the hay by adopting a balanced supplementation, which in fact allows overall good performance but increases production costs	**A3a**. Use of feed blocks containing molasses and urea in order to increase the digestibility of the roughage
High neonatal mortality	The farmer is fully aware of this production loss: a veterinary assistance to prevent cases of abortions and myodystrophy would be needed. Moreover the farmer may need veterinary assistance for a better management of pregnant ewes (ecography), particularly if the selection scheme has to be relaunched	**A1**. Demonstration Action based on a veterinary consulting service for the applying of "Sementusa protocol ®", based on ecography of ewes and rams in key periods of the year and the management of key data to evaluate the reproduction performance of the flock along with the reproductive season
Moderately low milk yield	The farmer is fully aware of this problem. Despite of a long history of genetic improvement through the use of selected rams, in the last year, the lack of testing-day services by APA (Province Breeder Association) has limited the proper selection of ewes to be mated or culled	**A2a** and **A2b**. Implementation of a milk production daily-test in mid lactation
High soil tillage intensity and fuel consumption	The farmer is aware of it and considers soil tillage operations might be reduced by establishing persistent pastures	**B1 a.** 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. Furthermore, minimum tillage techniques are currently tested on the farm
	The farmer is aware of it and considers soil tillage operations might be reduced by establishing a perennial short-lived legume (sulla)	**B2.** Establishment of sulla

Implemented action 5.B1 - Partner responsible: Agris.

Name of the implemented mitigation action: Use of feedblocks to improve diet digestibility in sheep

Period	July – December 2018
Critical issues detected	Low digestibility of the diet of sheep grazing on stubble and fed with poor quality hays during pregnancy.
Objective of the action	Better efficiency of feed use as experimentally verified in pregnant sheep
Description of the action	Feedblocks based on molasses and palm oil and mineral-vitamin blocks were made available with a ratio of 1 block 25-30 sheep grazing cereal stubble and then in the feeders where the animals were fed with grass hay to libitum. Expected consumption was 50 g/head d for food blocks, around 20 g/head d for mineral-vitamin blocks.
Expected results	Increased diet digestibility (with consequent lower emission per kg of ingested SS). Better nutritional status and milk production in early lactation.
	Farm visits devoted to the action
Date	Activity
July 17, 2018	Preliminary assessment of ecological hotspots
August 1, 2018	Starting feedblock utilization on cereal stubble
September 25, 2018	Feedblock intake monitoring
November 12, 2018	Feedblock intake monitoringF
November 15, 2018	Monitoring activity – field visit
December 21, 2018	Management data collection
January 10, 2019	Feedstuff sampling and management data collection

Measured/estimated technical results: forage production, animal production and consumptions	Expected consumption was 50 g / head d for food blocks, around 20 g / head d for mineral-vitamin ones. A modeling exercise has been run in order to estimate the impact of using the feeding blocks considering two levels of response: L1, increase of diet OM digestibility by 2 units; L2, increase of diet OM digestibility by 4 units.
Environmental impact (carbon footprint) pre and post-action	CF pre-mitigation = 4.15 kg $CO_{2\ eq}$/kg FPCM Post-L1 = 4.04 kg $CO_{2\ eq}$/kg FPCM (-3%) Post-L2 = 4.00 kg $CO_{2\ eq}$/kg FPCM (-4%)
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Total income Pre-mitigation € 44867 Post-level 1 € 45395 Post-level 2 € 45395 Variable costs Pre-mitigation € 28635 Post-level 1 € 29178 Post-level 2 € 29178 Gross margin Pre-mitigation € 16232 Post-level 1 € 15940 (-2%) Post-level 2 € 16217 – (-0.0)

Implemented action 5.A2. - Partner responsible: Agris………………………………..

Name of the implemented mitigation action: A2a and A2b. Improvement of milk productivity through individual milk recording

Period	Winter 2019
Critical issues detected	Milk production can be improved, given the genetic basis of the farm.
Objective of the action	1.Better feeding efficiency by dividing the flock into groups at different production levels 2. Reduction of the permanence of less productive animals on the farm with an early culling and consequent reduction in production costs and emission intensity
Description of the action	An individual milk recording of all ewes associated with the BC scoring carried out by the ARAS technician was carried out
Expected results	Reduced use of concentrates and increased milk production thanks to a better culling strategy
	Farm visits devoted to the action
Date	Activity
27-28 March 2019	Individual measurement of milk yield and milk sampling

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	The milk recording has shown above all a positive effect on the accuracy of culling. In practice, the check made it possible to feed the sheep of the two groups more adequately and to anticipate the matings of the less productive ewes.
Environmental impact (carbon footprint) pre and post-action deployment	A modeling was carried out by comparing the pre status with n. 2 intervention variants: a) use of flowmeters; b) APA recordings for an earlier culling of less productive ewes; (<0.5 l / d). In both cases there is a limited mitigation effect considering only the direct impact of the action with CF that goes from 4.15 to 4.06 (variant a) to 4.04 (variant b) kg CO_2 eq./kg FPCM.
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	From the aforementioned modeling, the estimates of revenues and costs were: Total income: Pre-mitigation: € 45269 Post-mitigation € 44867 (variant a); Post-mitigation € 444527 (variant b); Variable costs + depreciation equipment Pre- € 28635; Post- € 30203 (variant a) Post- € 28465 (variant b) Gross Margin; Pre: € 16232; Post- € 14324 (variant a) -12% Post- € 16804 (variant b) +3.5%

Implemented action 5.A1 Partner responsible: Agris……………………………..

Name of the implemented mitigation action: Improvement of reproduction efficiency

Period	February 2020 – March 2021
Critical issues detected	Neonatal lamb mortality, low fertility of primiparous ewes
Objective of the action	Increased fertility and reduced mortality of lambs whith increase in production and reduction of emission intensity
Description of the action	The activity follows the so-called "Sementusa" protocol. The action involves increasing the reproductive efficiency through veterinary inspection of the flock and selection of the sheep on the basis of the health status (deducible from the analysis of blood samples, feces and ultrasound scanning).
Expected results	Increased fertility, increased milk production due to the reduction of unproductive animals, higher lamb meat production.
	Farm visits devoted to the action
Date	Activity
February 27, 2020	Ram inspection to assess their health status

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Implemented action 5.B1a – responsible: CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of an annual forage crop by a permanent pasture

Period	From October 2018 (modelization refer to year 2016/2017)
Critical issues detected	High cultivation intensity of farm area, which involves a high consumption of fuel and other energy inputs.
Objective of the action	Reduction of the economic, working and organizational burdens deriving from the frequent cultivation of soil for forage production, and relative improvement of environmental performance (reduction of GHG emissions, reduction of soil erosion, improvement of the C stock in the soil)
Description of the action	Revision of annual cultivation plan, with the replacement of a part of the area usually devoted to annual crops with improved perennial pastures, consisting of mixtures of perennial and self-seeding leguminous and graminaceous species. In detail, we proceed with the minimum tillage and sowing of the mixture by a seed broadcaster. Pasture management involves rotational grazing and 1-3 flail mowing to control weeds after grazing. Grazing season is stopped at flowering to favour re-seeding, which is fundamental especially the first year to ensure the resilience of the pasture.
Expected results	Reduction of fodder self-production costs and relative reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment of annual forage crops; ii) Reduction of working costs and working times necessary for fodder production, with relative improvement of work organization and planning in the autumn; iii) Reduction of GHG emissions due to less use of energy inputs; iv) Reduction of soil erosion due to the lower intensity of the work involved; v) Improvement of soil fertility with an increase in the stock of organic C, favored by slow mineralization processes.
	Farm visits devoted to the action
Date	Activity
July 2018	Preliminary assessment of ecological hotspots
November 15, 2018	Monitoring visit
November 20, 2018	Soli sampling
November 25, 2018	Ploughing
December 13, 2018	Harrowing
December 14, 2018	Sowing of pasture mixture with seed cover
February 19, 2019	Monitoring visit
March 6, 2019	Herbage mass sampling
April 17, 2019	Herbage mass sampling
May 10, 2019	Flail mowing
May 23, 2019	Monitoring visit
June 30, 2019	Flail mowing
September 19, 2019	Monitoring visit
October 27, 2019	Monitoring visit
December 28, 2019	Monitoring visit

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Forage crop (mix grass-legumes): - Estimated equivalent biomass production: 4.80 t DM ha^{-1} - Fertilizer consumption: 83 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} - Diesel consumption: 47 liters ha^{-1} - working hours: 4.82 h ha^{-1} Improved pasture (annual average values - 3 years of pasture duration are considered): - Estimated equivalent biomass production: 3.37 t DM ha^{-1} - Fertilizer consumption: 0 kg N ha^{-1} - Diesel consumption: 19 liters ha^{-1} - working hours: 2.25 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	*Level 1* (system boundary represented by the single 2.2 ha plot) a) Climate Change (FU: t DM biomass equivalent) - forage crop: 294 kg CO_{2-eq} per t DM - improved pasture: 19 kg CO_{2-eq} per t DM b) Climate Change (FU: ha UAA) - forage crop: 1413 kg CO_{2-eq} per ha - improved pasture: 93 kg CO_{2-eq} per ha *Level 2* (border of the system represented by the entire production system, with the replacement of 6.65 ha of forage crop with improved pasture) c) Climate Change (FU: 1 kg FPCM) - forage crop: 4.15 kg CO_{2-eq} per kg FPCM - improved pasture: 3.94 kg CO_{2-eq} per kg FPCM
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	- Forage crop: 71 € t DM^{-1} equivalent biomass - Improved pasture: 39 € t DM^{-1} of biomass equivalent - Economic savings: Improved pasture vs forage crop (per t DM of biomass equivalent) a) 32 € t DM^{-1} b) 45% t DM^{-1} - Improved pasture area necessary to equal the yield of the grass: 1.42 ha - Labor savings: Improved pasture vs forage crop (per ha UAA) a) 1.62 h ha^{-1} b) 34% ha^{-1}

Implemented action 5.B1b - Partner responsible: CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of a natural pasture with an improved perennial pasture

Period	From November 2018 (modelization refer to year 2016/2017)
Critical issues detected	Limited fodder productivity of natural pastures, with low yield of biomass available for grazing and low quality of herbage on offer
Objective of the action	Increase of pasture production, with improvement of the quality. Improvement of environmental performance, with reduction of GHG emissions in relation to the improvement of the digestibility of the fodder biomass offered
Description of the action	Over-seeding of perennial and self-seeding leguminous and graminaceous species. In detail, we proceeded with minimal tillage (harrowing) and sowing the mixture. Crop management involved rotational grazing associated with flail mowing (from 1 to 3 operations per year), with the aim of controlling weeds. Grazing was stopped at flowering which is fundamental to ensure the resilience of the pasture, especially the first year.
Expected results	i) Improvement of the quality of self-produced biomass; ii) Greater productivity of pasture and consequent greater capacity for self-supply; iii) Reduction of GHG emissions in relation to greater digestibility of forage;
	Farm visits devoted to the action
Date	Activity
See 5.4. form	See 5.4 form

-1

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	**Natural pasture** - Estimated equivalent biomass production: 1.60 t DM ha^{-1} - Diesel consumption: 23 liters ha^{-1} - h of work: 2.50 h ha^{-1} **Improved pasture** (annual average values obtained from the 8-year pasture duration are considered): - Estimated equivalent biomass production: 4.25 t DM ha^{-1} - Diesel consumption: 15 liters ha^{-1} - working hours: 1.78 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	*Level 1* (system boundary represented by the single plot of 1.59 ha) a) Climate Change (FU: t DM biomass equivalent) - **natural pasture**: 331 kg CO_{2-eq} per t DM - **improved pasture**: 11 kg CO_{2-eq} per t DM b) Climate Change (FU: UAA) - **natural pasture**: 529 kg CO_{2-eq} per ha - **improved pasture**: 25 kg CO_{2-eq} per ha *Level 2* (border of the system represented by the entire production system, with interventions to improve pasture on 5.58 ha of natural pasture) c) Climate Change (FU: 1 kg FPCM) - **natural pasture**: 4.15 kg CO_{2-eq} per kg FPCM - **improved pasture**: 3.94 kg CO_{2-eq} per kg FPCM
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Only out-of-pocket expenses (cost of inputs used in the production of fodder biomass) included in the crop account are considered: - **Natural pasture**: 12 € t DM^{-1} of equivalent biomass - **Improved pasture**: 13 € t DM^{-1} of equivalent biomass - Economic savings Improved natural pasture vs natural pasture (per t DM of biomass equivalent) a) -1 € t DM^{-1} b) -10% t DM^{-1} - Improved pasture area necessary to equal the yield of natural pasture: 0.38 ha - Labor savings Improved natural pasture vs natural pasture (per Ha UAA equivalent) a) 1.83 h ha^{-1} b) 73% ha^{-1}

NOTE: the level 2 of CF value (system boundaries = entire production system of the company, with FU = 1 kg FPCM) has been calculated by introducing both the pasture improvement interventions in the new scenario, which include the replacement of the forage crop and the improvement of natural pasture. In the new scenario, all the other processes related to these two interventions have also been modified, e.g. the sheep diets. The following are the CF values for the two scenarios, pre and post intervention:

- natural pasture (with forage crop and natural pasture): 4.15 kg CO_{2-eq} kg $FPCM^{-1}$
- mitigation scenario (with improved pasture on former forage crop and improved pasture on former natural pasture): 3.83 kg CO_{2-eq} kg FPCM

Implemented action 5.B2 - responsible CNR-IBE / CNR-ISPAAM and LAORE

Name of the implemented mitigation action: Replacement of an annual forage crop with sulla (short-lived perennial legume)………………………………………………………….

Period	From October 2018 (modelled impact refers to year 2016/2017)
Critical issues detected	High intensity of annual processing of company surfaces, with consequent high fuel consumption and onerous workload, both in economic and organizational terms.
Objective of the action	Reduction of work and organizational costs deriving from the frequent soil tillage for forage production, and related improvement of environmental performance (reduction of GHG emissions). Improvement of the quality of fodder biomass and increase of the milk yield per lactating ewe.
Description of the action	Revision of the cropping plan, with the replacement of a part of the areas invested in grass with a biennial plant. In detail, the soil is tilled, the seed is inoculated and then sown. Crop management involves rotational grazing associated with flail mowing (from 1 to 2 operations per year), with the aim of controlling weeds.
Expected results	i) Reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment and management of annual forage crops; ii) Reduction of workloads and work times necessary for fodder production, with relative improvement of the organization and planning of farm activities in the autumn; iii) Improvement of the quality of the self-produced forage biomass and of the milk yields per lactating ewe; iii) Reduction of GHG emissions due to less use of energy inputs.
	Farm visits devoted to the action
Date	Activity
June 2018	Preliminary assessment of hotspots
September 20, 2019	Manuring
November 14, 2019	Subsoiling
November 15, 2019	Harrowing
November 16, 2019	Inoculum preparation and seed treatment
November 17, 2019	Sowing, harrowing and rolling
December 11, 2019	Monitoring visit
Ferbruary 28, 2020	Fertilizer broadcasting
April 20, 2020	Mechanical weeding by a mower

Environmental impact (carbon footprint) pre and post-action deployment	Data are not yet available
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	
Environmental impact (carbon footprint) pre and post-action deployment	

Implemented action 5.C1. Partner responsible: Laore/CNR-IBE/CNR-ISPAAM

Name of the implemented mitigation action: minimum tillage and on-row sowing (fodder crops)

Period	The critical issues relate to the year 2016/17 – Intervention from January 2020
Crtical issues detected	High soil tillage intensity and fuel consumption due to the conventional tillage used for crop implantation.
Objective of the action	Reduction of soil tillage intensity, where part of conventional tillage is substituted by minimum tillage and on-row sowing. In detail, the intervention aims to reduce the cost of crop implantation, the GHG emission and the soil organic matter degradation.
Description of the action	Partial replacement of conventional tillage (ploughing, harrowing, sowing with spreader and seed covering) with minimum tillage carried out using a combined machine, consisting of a grubber, crusher discs and toothed roller. Subsequently, it was carried out the on-row sowing.
Expected results	a) Reduction of energy input utilization and work costs as diesel and oil consumption, amount of seeds used for sowing and machinery consumption; b) Reduction of working time needed to carry out the annual soil tillage and cultivation practices; c) Reduction of greenhouse gases emission due to the decrease of energy input utilization; d) Improvement of the soil fertility thanks to the reduction of soil organic matter mineralization.
	Farm visits devoted to the action
Date	Activity
September 2019	Preliminary assessment of ecological hotspots
15th October 2019	Monitoring activity
5th January 2020	Minimum tillage
6th January 2020	On-row sowing
8th January 2020	Operation with roller
2nd March 2020	Spreader fertilization
24th May 2020	Haymaking operation
28th-30th May 2020	Hay harvesting operation

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Conventional tillage (fodder crops – ryegrass and clover): - Biomass yield: 3.01 t DM ha^{-1} - Diesel consumption: 64 Litres ha^{-1} - Work hours: 6.80 h ha^{-1} Minimum tillage + on-row sowing (fodder crops – ryegrass and clover): - Estimated biomass yield: 2.75 t DM ha^{-1} - Diesel consumption: 67 Litres ha^{-1} Work hours: 6.4 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	Data are not yet available
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Production cost of the biomass: - Conventional tillage: 117 € t DM^{-1} of biomass - Minimum tillage + on-row sowing: 91 € t DM^{-1} of biomass - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) a) 27 € t DM^{-1} b) 23% t DM^{-1} - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) a) 0.43 h ha^{-1} 6% ha^{-1}

Implemented action 5.8 - Partner responsible: Laore/CNR-IBE/CNR-ISPAAM

Name of the implemented mitigation action: minimum tillage and on-row sowing (cereal crops)

Period	The critical issues relate to the year 2016/17 – Intervention from January 2020
Crtical issues detected	High soil tillage intensity and fuel consumption due to the conventional tillage used for crop implantation.
Objective of the action	Reduction of soil tillage intensity, where part of conventional tillage is substituted by minimum tillage and on-row sowing. In detail, the intervention aims to reduce the cost of crop implantation, the GHG emission and the soil organic matter degradation.
Description of the action	Partial replacement of conventional tillage (ploughing, harrowing, sowing with spreader and seed covering) with minimum tillage carried out using a combined machine, consisting of a grubber, crusher discs and toothed roller. Subsequently, it was carried out the on-row sowing.
Expected results	a) Reduction of energy input utilization and work costs as diesel and oil consumption, amount of seeds used for sowing and machinery consumption; b) Reduction of working time needed to carry out the annual soil tillage and cultivation practices; c) Reduction of greenhouse gases emission due to the decrease of energy input utilization; d) Improvement of the soil fertility thanks to the reduction of soil organic matter mineralization.
	Farm visits devoted to the action
Date	Activity
September 2019	Preliminary assessment of ecological hotspots
15th October 2019	Monitoring activity
5th January 2020	Minimum tillage
6th January 2020	On-row sowing
8th January 2020	Operation with roller
2nd March 2020	Spreader fertilization
June 2020	Harvesting

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Conventional tillage (fodder crops – ryegrass and clover): - Biomass yield: 3.76 t DM ha^{-1} - Diesel consumption: 105 Litres ha^{-1} - Work hours: 8.20 h ha^{-1} Minimum tillage + on-row sowing (fodder crops – ryegrass and clover): - Estimated biomass yield: 3.42 t DM ha^{-1} - Diesel consumption: 76.6 Litres ha^{-1} Work hours: 6.1 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	Data are not yet available
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Production cost of the biomass: - Conventional tillage: 86 € t DM^{-1} of biomass - Minimum tillage + on-row sowing: 55 € t DM^{-1} of biomass - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) c) 31 € t DM^{-1} d) 36% t DM^{-1} - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) b) 2.13 h ha^{-1} 26% ha^{-1}

Pastures improvement in Cugusi farm

Farm 6 – Ena Francesco

Farm characteristics		Farm 6 - Ena
Geographical areas		South
Pedologic substrate		Alluvial
Altitude	m a.s.l.	17
Total Agricultural Area (TAA)	ha	39.1
Utilized Agricultural Area (UAA)	ha	38.9
Natural pasture area	%	0
Annual forage crops	%	79
Heads (number of mature ewes)	N	280
Stocking rate	head ha^{-1}	8.3
Fertility of mature ewe	%	98
Neonatal lamb mortality (1)	%	9
Milk total annual production	kg FPCM	40,139
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	123.5
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	1.11
Feed Self-Sufficiency	% (Dry Matter)	75
Work units	N	3
Electricity consumption	kWh 100 kg $FPCM^{-1}$	10.2
Diesel consumption	Lt 100 kg $FPCM^{-1}$	9.9

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
High percentage of tilled land every year: high soil tillage intensity and fuel consumption	The farmer is aware of the problem, considers that soil tillage may be reduced through the establishment of persistent pastures, but needs technical support	**B1a**. To establish a persistent pasture, reduce soil tillage intensity and hence the carbon footprint
Low quality of conserved forages	The farmer is aware of the problem and interested to evaluate alternative conservation techniques	**B3.** Improvement of conserved forage digestibility by early cutting of herbage (B3a) or haylage wrapped bale production (B3b)

Implemented action 6.B1a - Partner responsible CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of irrigated annual forage crop by perennial improved pasture……………………………………………………………………..

Period	From November 2018 (modelization refer to year 2016/2017)
Critical issues detected	High cultivation intensity of farm area, which involves a high consumption of fuel and other energy inputs
Objective of the action	Reduction of the economic, working and organizational burdens deriving from the frequent cultivation of soil for forage production, and relative improvement of environmental performance (reduction of GHG emissions, reduction of soil erosion, improvement of the C stock in the soil)
Description of the action	Revision of annual cultivation plan, with the replacement of a part of the area usually devoted to irrigated annual crops with improved perennial pastures, consisting of mixtures of perennial and self-seeding leguminous and graminaceous species. In detail, we proceed with the minimum tillage and sowing of the mixture by a seed broadcaster. Pasture management involves rotational grazing and 1-3 flail mowing to control weeds after grazing. Grazing season is stopped at flowering to favour re-seeding, which is fundamental especially the first year to ensure the resilience of the pasture.
Expected results	Reduction of fodder self-production costs and relative reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment of annual forage crops; ii) Reduction of working costs and working times necessary for fodder production, with relative improvement of work organization and planning in the autumn; iii) Reduction of GHG emissions due to less use of energy inputs; iv) Reduction of soil erosion due to the lower intensity of the work involved; v) Improvement of soil fertility with an increase in the stock of organic C, favored by slow mineralization processes.

	Farm visits devoted to the action
Date	Activity
July 2018	Preliminary assessment of ecological hotspots
November 12, 2018	Monitoring visit
November 14, 2018	Soil sampling
November 15, 2018	Ploughing
November 16, 2018	Harrowing
November 17, 2018	Sowing of pasture mixture
February 19, 2019	Monitoring visit
March 28, 2019	Herbage mass sampling
May 20, 2019	Monitoring visit
September 19, 2019	Monitoring visit
October 20, 2019	Monitoring visit

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Implemented action 6.B3 - Partner responsible: UNISS- Department of Agricultural Sciences

Name of the implemented mitigation action: B6 – Production of early cut hay and wrapped (and chopped) bale silage

Period	Winter 2019- Spring 2020 Seasons
Critical issues detected	On-farm low quality forages
Objective of the action	Increase the digestibility of on-farm produced forages and especially the quality of forage (in terms of high CP and low NDF contents)
Description of the action	Use of innovative haymaking tecniques to produce early cut hay and wrapped (and chopped) bale silage. These tecniques are realized anticipating the temporal windows of cutting (optimal phenological stage) and reducing the temporal windows of haymaking (2 days) which preserve forage from adverse weather condition that can occur during traditional haymaking (6-7 days)
Expected results	Improvement of enviromental and productive performance. Specifically, produce more milk, reduce enteric CH_4 per kg of FPCM, reduce the amount of off-farm feeds especially those rich in protein such as alfalfa and soybean meal and thus the emissions linked to them (GHG emissions from off-farm produced feeds)
	Farm visits devoted to the action
Date	Activity
January, 17 2020	Monitoring field
January, 24 2020	Monitoring field
January, 31 2020	Monitoring field
February, 6 2020	Monitoring field
February, 13 2020	Monitoring field
February, 20 2020	Monitoring field
February, 27 2020	Monitoring field
March, 3 2020	Monitoring field
	No activity for irrigation system problems and for CO-VID pandemy

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Not estimated
Environmental impact (carbon footprint) pre and post-action deployment	Not estimated
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Not estimated

Pasture improvement in Ena farm

Farm 7 – Mulas Mariano

Farm characteristics		Farm 7 - Mulas
Geographical area		South
Pedologic substrate		Alluvial
Altitude	m a.s.l.	121
Total Agricultural Area (TAA)	ha	189.1
Utilized Agricultural Area (UAA)	ha	182.3
Natural pasture area	%	0.0
Annual forage crops	%	100
Heads (number of mature ewes)	N	1312
Stocking rate	head ha^{-1}	7.2
Fertility of pluriparous ewe	%	96.7
Fertility of primiparous ewe	%	89.2
Neonatal lamb mortality [(1)]	%	7.7
Milk total annual production	kg FPCM	277,577
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	211.6
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.82
Feed Self-Sufficiency	% (Dry Matter)	70.4
Work units	N	4.5
Electricity consumption	kWh 100 kg $FPCM^{-1}$	7.7
Diesel consumption	Lt 100 kg $FPCM^{-1}$	6.26

[(1)] (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low fertility and low concentration of lambings. This means that many ewes lamb late in winter with lower return from meat (low lamb price after Christmas) and putatively lower return from milk (decay of forage quality in spring).	The farmer is aware of it but due to the high flock size he is unable to store and manage adequately the data of mating and do not perform a systematic control of mating efficiency by sheep scanning.	**A1.** Demonstration Action based on a veterinary consulting service for the applying of “Sementusa protocol ®”, based on ecography of ewes and rams in key periods of the year and the management of key data to evaluate the reproduction performance of the flock along with the reproductive season
High footrot incidence	The farmer is fully aware and tries to manage the problem but separating the affected animals an treating them by drugs	**A1**. Vaccination and adequate prophylaxis by a Veterinary assistance service (see above)
Low feed self-sufficiency	The farm adopts an intensified production plan which can be possibly improved by the establishment of a forage crops able to persist more than one year	**B2.** To establish sulla on 2 ha plots in order to reduce the soil tillage intensity and hence the carbon foot print

Implemented action 7.A1. - Partner ShToSh responsible: Agris……………………………..

Name of the implemented mitigation action: Improvement of reproduction efficiency

Period	February 2020 – March 2021
Critical issues detected	Neonatal lamb mortality, low fertility of primiparous ewes
Objective of the action	Increased fertility and reduced mortality of lambs whith increase in production and reduction of emission intensity
Description of the action	The activity follows the so-called "Sementusa" protocol. The action involves increasing the reproductive efficiency through veterinary inspection of the flock and selection of the sheep on the basis of the health status (deducible from the analysis of blood samples, feces and ultrasound scanning).
Expected results	Increased fertility, increased milk production due to the reduction of unproductive animals, higher lamb meat production.
	Farm visits devoted to the action
Date	Activity
January 28, 2020	Ecography of non-lambed (barren) ewes
February 27, 2020	Ram inspection to assess their health status

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Implemented action 7.B2 - Partner responsible: CNR-IBE / CNR-ISPAAM and LAORE

Name of the implemented mitigation action: Replacement of an irrigated forage crop with sulla (short-lived perennial legume)……………………………………………………..

Period	From October 2018 (modelled impact refers to year 2016/2017)
Critical issues detected	High intensity of annual processing of company surfaces, with consequent high fuel consumption and onerous workload, both in economic and organizational terms.
Objective of the action	Reduction of work and organizational costs deriving from the frequent soil tillage for forage production, and related improvement of environmental performance (reduction of GHG emissions). Improvement of the quality of fodder biomass and increase of the milk yield per lactating ewe.
Description of the action	Revision of the cropping plan, with the replacement of a part of the areas invested in grass with a biennial plant. In detail, the soil is tilled, the seed is inoculated and then sown. Crop management involves rotational grazing associated with flail mowing (from 1 to 2 operations per year), with the aim of controlling weeds.
Expected results	i) Reduction of the use of energy inputs, such as fuel, oil, seeds and fertilizer usually used in the establishment and management of annual forage crops; ii) Reduction of workloads and work times necessary for fodder production, with relative improvement of the organization and planning of farm activities in the autumn; iii) Improvement of the quality of the self-produced forage biomass and of the milk yields per lactating ewe; iii) Reduction of GHG emissions due to less use of energy inputs.
	Farm visits devoted to the action
Date	Activity
July 2018	Preliminary assessment of hotspots
November 4, 2019	Ploughing
November 5, 2019	Harrowing
November 6, 2019	Inoculum preparation and seed treatment
November 7, 2019	Sowing, harrowing and rolling
December 11, 2019	Monitoring visit
March 28, 2019	Monitoring visit
June 5, 2019	Monitoring visit
November 4, 2019	Monitoring visit

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

Implemented action 7.3 - Partner responsible: Laore/CNR-IBE/CNR-ISPAAM

Name of the implemented mitigation action: minimum tillage and on-row sowing (fodder crops)

Period	The critical issues relate to the year 2016/17 – Intervention from January 2020
Crtical issues detected	High soil tillage intensity and fuel consumption due to the conventional tillage used for crop implantation.
Objective of the action	Reduction of soil tillage intensity, where part of conventional tillage is substituted by minimum tillage and on-row sowing. In detail, the intervention aims to reduce the cost of crop implantation, the GHG emission and the soil organic matter degradation.
Description of the action	Partial replacement of conventional tillage (ploughing, harrowing, sowing with spreader and seed covering) with minimum tillage carried out using a combined machine, consisting of a grubber, crusher discs and toothed roller. Subsequently, it was carried out the on-row sowing.
Expected results	a) Reduction of energy input utilization and work costs as diesel and oil consumption, amount of seeds used for sowing and machinery consumption; b) Reduction of working time needed to carry out the annual soil tillage and cultivation practices; c) Reduction of greenhouse gases emission due to the decrease of energy input utilization; d) Improvement of the soil fertility thanks to the reduction of soil organic matter mineralization.
	Farm visits devoted to the action
Date	Activity
September 2019	Preliminary assessment of ecological hotspots
15th October 2019	Monitoring activity
5th January 2020	Minimum tillage
6th January 2020	On-row sowing
8th January 2020	Operation with roller
2nd March 2020	Spreader fertilization
24th May 2020	Haymaking operation
28th-30th May 2020	Hay harvesting operation

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Conventional tillage (fodder crops – ryegrass and clover): - Biomass yield: 3.69 t DM ha^{-1} - Diesel consumption: 93 Litres ha^{-1} - Work hours: 8.08 h ha^{-1} Minimum tillage + on-row sowing (fodder crops – ryegrass and clover): - Estimated biomass yield: 3.68 t DM ha^{-1} - Diesel consumption: 66 Litres ha^{-1} Work hours: 6.17 h ha^{-1}
Environmental impact (carbon footprint) pre and post-action deployment	<u>Level 1 (system boundary: plot of 3 ha)</u> a) Climate Change (FU: t DM biomass) - Conventional tillage: 293 kg CO_{2-eq} per t DM Minimum tillage + on-row sowing: 262 kg CO_{2-eq} per t DM
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Production cost of the biomass: - Conventional tillage: 81 € t DM^{-1} of biomass - Minimum tillage + on-row sowing: 67 € t DM^{-1} of biomass - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) A. 14 € t DM^{-1} B. 18% t DM^{-1} - Economic savings Minimum tillage + on-row sowing *vs* Conventional tillage (per t DM biomass) A.1.92 h ha^{-1} B. 24% ha^{-1}

GRANITIC AREA

Farm 8 – Molozzu Peppino e Gavino

Farm characteristics		Farm 8 - Molozzu
Geographical area		Centre
Pedologic substrate		Granitic
Altitude	m a.s.l.	540
Total Agricultural Area (TAA)	ha	79.3
Utilized Agricultural Area (UAA)	ha	79.3
Natural pasture area	%	66.7
Annual forage crops	%	33.3
Heads (number of mature ewes)	N	240
Stocking rate	head ha^{-1}	3.0
Fertility of mature ewe	%	83.3
Neonatal lamb mortality (1)	%	2.5
Milk total annual production	kg FPCM	29,692
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	123.7
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	1.1
Feed Self-Sufficiency	% (Dry Matter)	73.9
Work units	N	1.5
Electricity consumption	kWh 100 kg $FPCM^{-1}$	0.76
Diesel consumption	Lt 100 kg $FPCM^{-1}$	7.7

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low forage quality and productivity of natural pastures	The farmers are aware of the problem and they are inclined to the innovative interventions to improve the productive system efficiency; they need to be driven in this intervention plans	**B1b.** Natural pasture improvement interventions in a 2 ha area with overseeding of perennial and self-reseeding grass-legume mixture
Low ewe fertility, especially for ewes lamb selected for replacement	The farmer is aware of it but he doesn't know how to improve this situation. He shows openness towards possible channels of improvement and innovation. Technical support is needed	**A1**. Improvement of reproductive performance with a veterinary consulting service for the applying of "Sementusa protocol ®", based on monitoring and operative interventions on ewes and rams

Implemented action 8.B1b. - Partner responsible CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of a natural pasture with an improved perennial pasture

Period	From October 2018 (modelization refer to year 2016/2017)
Critical issues detected	
Objective of the action	Increase of pasture production, with improvement of the quality. Improvement of environmental performance, with reduction of GHG emissions in relation to the improvement of the digestibility of the fodder biomass offered
Description of the action	Over-seeding of perennial and self-seeding leguminous and graminaceous species. In detail, we proceeded with minimal tillage (harrowing) and sowing the mixture. Crop management involved rotational grazing associated with flail mowing (from 1 to 3 operations per year), with the aim of controlling weeds. Grazing was stopped at flowering which is fundamental to ensure the resilience of the pasture, especially the first year.
Expected results	i) Improvement of the quality of self-produced biomass; ii) Greater productivity of pasture and consequent greater capacity for self-supply; iii) Reduction of GHG emissions in relation to greater digestibility of forage
Farm visits devoted to the action	
Date	Activity
July 2018	Preliminary assessment of ecological hotspots
November 6, 2018	Monitoring visit
November 30, 2018	Soil sampling
December 17, 2018	Pasture mixture overseeding on natural pasture
February 19, 2019	Monitoring visit
May 13, 2019	Monitoring visit
June 27, 2019	Monitoring visit
July 30, 2019	Monitoring visit
October 10, 2019	Monitoring visit

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available.
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

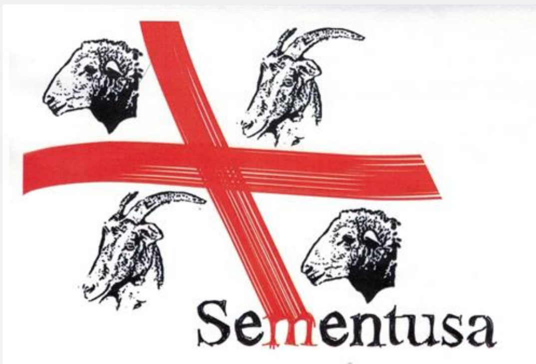
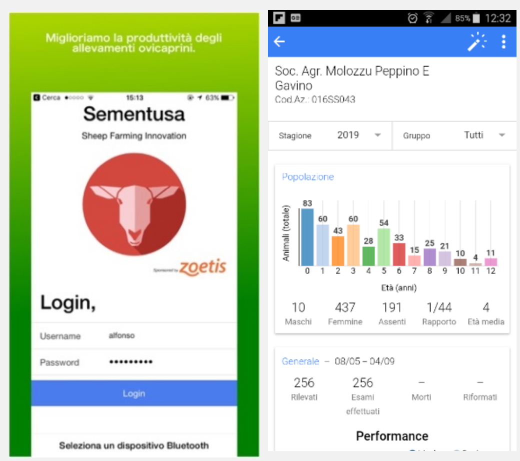
Implemented action 8.A1 – Partner responsible: UNISS-Department of Agricultural Sciences

Name of the Name of mitigation action: A1 – Improving reproduction efficiency trought the application of "Sementusa" protocol

Period	From April 30 2019 until now
Critical issues detected	Low fertility of primiparous ewes (25%) and low productivity
Objective of the action	Enhance reproductive efficiency in order to improve environmental and productive performance
Description of the action	Improve reproductive efficiency trought veterinary ispection and selection of ewes in relation to health status (evaluated trought analysis of blood and fecal samples, ecografies and body condition score)
Expected results	Higher fertility rate, higher milk production, lower environmental impact, higher price of lamb meat
	Farm visits devoted to the action
Date	Activity
April, 30 2019	Veterinary ispection, ecography and collection of biological samples
May, 7 2019	Veterinary ispection, ecography and collection of biological samples
August, 7 2019	Veterinary ispection, ecography and collection of biological samples
October, 2 2019	Veterinary ispection, ecography and collection of biological samples
October, 30 2019	Veterinary ispection, ecography and collection of biological samples
From November 2019 to January 2020	Veterinary ispection, ecography and collection of biological samples Ispezione veterinaria gregge, ecografie e raccolta campioni biologici
March, 2020	Veterinary ispection, ecography and collection of biological samples

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Reproduction improvement (fertility rate: 100%) lowered on average 20% of GHG emissions
Environmental impact (carbon footprint) pre and post-action deployment	4.23 vs 3.39 kg $CO_{2\ eq}$ kg $FPCM^{-1}$ (pre and post-action deployment, respectively)
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	- Revenues: 24892.90 vs 31433.50 Euro (pre and post-action deployment). The annual lamb sales (kg) and the total milk sold (L) increased by 37% and 25%, respectively. - Total Feeding cost: 10907 vs 11501 Euros (pre and post-action deployment, respectively) - Annual Feeding cost per head: 37 vs 39 Euros head-1 per year-1 (pre and post-action deployment, respectively) -Annual veterianary cost: 6 euro head-1 year-1 - Ratio between Renvenues and Total Cost (Feeding +Veterinary service): 2.28 vs 2.37 (pre and post-action deployment, respectively)

Improvement actions in Molozzu farm

<table>
<tr><th colspan="2">Livestock intervention – Improvement of flock fertility</th></tr>
<tr><td>
</td><td></td></tr>
<tr><td>a) Sementusa Logo</td><td>b) Ram inspection (evaluation of reproductive organs)</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">c) Fecal and blood samples collection of the flock</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>d) evaluation of ewes lambs selected for replacement</td><td>e) SEMENTUSA app for the monitoring plan</td></tr>
</table>

Pastures improvement in Molozzu farm

Farm 9 – Orritos Matteo

Farm characteristics		Farm 9 - Orritos
Geographical area		Centre
Pedologic substrate		Granitic
Altitude	m a.s.l.	509
Total Agricultural Area (TAA)	ha	175
Utilized Agricultural Area (UAA)	ha	135
Natural pasture area	%	14.8
Annual forage crops	%	85.2
Heads (number of mature ewes)	N	810
Stocking rate	head ha^{-1}	6.0
Fertility of mature ewe	%	97.5
Neonatal lamb mortality [(1)]	%	24.6
Milk total annual production	kg FPCM	82,507
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	101.9
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	1.59
Feed Self-Sufficiency	% (Dry Matter)	72.6
Work units	N	2
Electricity consumption	kWh 100 kg $FPCM^{-1}$	17.7
Diesel consumption	Lt 100 kg $FPCM^{-1}$	6.2

[(1)] (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Low on-farm forages quality	Good farmer's propensity for change and innovation	***Action not implemented*** The interventions will focus on the management of haymaking and, in particular, on the production of alternative hays (wrapped bale silage) in order to: increase on-farm forages quality and preserve them under adverse weather conditions
High electric energy consumption	Good farmer's propensity for change and innovation	**D.** **I**nstallation of an inverter to reduce electricity consumption of milking operation

ACTION 9.D - PARTNER RESPONSIBLE: UNISS

Name of the implemented mitigation action: improvement of energetic efficiency in milking

Period	Lactation 2020-2021
Critical issue detected	High energy consumption for electricity; it has to be considered that in this farm electricity consumption is high both in terms of intensity and with respect to the percentage impact on greenhouse gas emissions and is one of the main items of possible mitigation in the company.
Objective of the action	Reducing emissions by reducing the electricity consumption of the milking plant
Description of the action	Installing of an inverter The inverter will include the control unit and a display of the operating parameters and is equipped with a vacuum sensor capable of detecting minimal fluctuations (even of only 0.1 kPa) ensuring a timely intervention of the frequency inverter, to maintain high stability of the vacuum level even in case of simultaneous fall of several milking clusters. The company's milking plant is 48 stalls with 24 clusters. The inverter will be coupled with the conventional vacuum regulator (by-pass). The reason for this intervention is to reduce the energy absorption of the vacuum pump, which is one of the main elements of the milking plant. The purpose of this operation is to increase operational efficiency while reducing energy consumption. The role of the inverter is to modulate the electric motor that drives the pump, in order to vary its rotation speed in relation to the vacuum level that is really necessary in the different phases of the milking routine. The inverter varies the frequency of the alternating current that feeds the motor so that it only delivers the power really needed to maintain the vacuum reserve. In addition to the reduction in electricity consumption, the associated advantages consist in a reduction in wear and tear of the system (with a consequent increase in duration and maintenance intervals) and lower noise levels for the benefit of animal welfare and operators. The replacement of the vacuum pump motor (currently 4.2 KW) will be evaluated because with the availability of the inverter it is possible to obtain the same performance with a motor of smaller size and power reduced by about 50% in large systems. An electric meter dedicated to the milking system will be installed to collect specific information on the improvement carried out.
Expected results	Improvement of energy performance to reduce milking electricity consumption. Compared to the size of the farm, it is estimated a level of energy consumption reduction equal to 50% of milking power consumption. This goal will be reached with the susbtituion of the engine power of the vacuum pump.
	Farm visits devoted to the action
Date	Activity
May 27, 2020	Inspection and preliminary visit to assess the feasibility of the intervention with the farmer.
June 9, 2020 (foreseeno)	Evaluation of inverter installation and modification of vacuum pump motor
June 2020	Installation of electrical and mechanical components
Julyo 2020	Preliminar evaluations

Nov.2020 – Feb.2021	Data Collection and Monitoring
February 2021	Complete action report

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Energy audit Survey of energy consumption and working time of the plant components; evaluation of the possibility of replacing the milking machine motor as the power currently required is 4 KW while with an inverter the power required could be reduced to a 3.0 KW motor. Comparison of the useful vacuum reserve when measuring the operating parameters of the milking machine control in collaboration with LAORE technicians.
Environmental impact (carbon footprint) pre and post-action deployment	Pre-intervention environmental impact: - pre: energy consumption of 0.20 KWh per kg of milk produced. - pre: emissions from electricity 0.07 kg of CO_2 eq per kg of milk produced Post-intervention environmental impact: estimated to reduce milking energy consumption by about 35%. - post: energy consumption of 0.14 KWh per kg of produced milk - post: emissions from electricity 0.05 kg of CO_2 eq per kg of produced milk
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	estimated calculations based on the information currently collected. Cost inverter 1750,00 euro complete with installation. Estimated duration 10 years (175,00 €uro per year) Estimated annual savings of about 550 € for reduced electricity consumption The action is in the planning stage

BASALTIC AREA

Farm 10 – Monte e' Fora Flli. Mura

Farm characteristics		Farm 10 – F.lli Mura
Geographical area		Centre
Pedologic substrate		Basaltic
Altitude	m a.s.l.	508
Total Agricultural Area (TAA)	ha	184.0
Utilized Agricultural Area (UAA)	ha	178.0
Natural pasture area	%	100.0
Annual forage crops	%	0.0
Heads (number of mature ewes)	N	695
Stocking rate	head ha^{-1}	3.9
Fertility of mature ewe	%	82.7
Neonatal lamb mortality (1)	%	4.8
Milk total annual production	kg FPCM	70,530
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	101.5
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	1.87
Feed Self-Sufficiency	% (Dry Matter)	67.9
Work units	N	2.5
Electricity consumption	kWh 100 kg $FPCM^{-1}$	10.2
Diesel consumption	Lt 100 kg $FPCM^{-1}$	5.6

(1) (stillborn lambs + lambs dead within 45 days) / lambs born

Hotspot	Farmer perception	Action plan
Decay of late summer pasture quality and low quality of on-farm made hay	The farmer is fully aware of this problem. Adverse weather pattern (rains) forced the farmer to mow lately in the season with a significant reduction of pasture's feed value during summer	**A3.** Use of feed blocks containing molasses and urea in order to increase the digestibility of the roughage
Low fertility of ewe-lambs due to abortions and low concentration of lambings	The farmer is aware of it. Due to the high flock size he is unable to store and manage adequately the data of matings and does not perform a systematic control of mating efficiency by sheep scanning.	**A1.** Demonstration Action based on a veterinary consulting service for the applying of "Sementusa protocol ®", based on ecography of ewes and rams in key periods of the year and the management of key data to evaluate the reproduction performance of the flock along with the reproductive season
High footrot incidence	The farmer is fully aware and tries to manage the problem separating the affected animals from the remaining of the flock an treating them by drugs	**A1.** Vaccination and adequate prophylaxis by a Veterinary assistance service (see above)

Implemented action 10.A3 Partner ShToSh responsible: Agris.

Name of the implemented mitigation action: Use of feedblocks to improve diet digestibility in sheep

Period	July – December 2018
Critical issues detected	Low digestibility of the diet of sheep grazing on stubble and fed with poor quality hays during pregnancy.
Objective of the action	Better efficiency of food use as experimentally verified in pregnant Sardinian sheep
Description of the action	Feedblocks based on molasses and palm oil and mineral-vitamin blocks were made available with a ratio of 1 block 25-30 sheep grazing cereal stubble and then in the feeders where the animals were fed with grass hay to libitum. Expected consumption was 50 g / head d for food blocks, around 20 g / head d for mineral-vitamin blocks.
Expected results	Increased diet digestibility (with consequent lower emission per kg of ingested SS). Better nutritional status and better milk production in early lactation.
	Farm visits devoted to the action
Date	Activity
17th July 2018	Preliminary assessment of ecological hotspots
1st August 2018	Starting feedblock utilization on cereal stubble
25th September 2018	Feedblock intake monitoring
12th November 2018	Feedblock intake monitoringF
15th November 2018	Monitoring activity – field visit
21th December 2018	Management data collection
10th January 2019	Feedstuff sampling and management data collection

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Expected consumption was 50 g / head d for food blocks, around 20 g / head d for mineral-vitamin ones. A modeling exercise has been run in order to estimate the impact of using the feeding blocks considering two levels of response: L1, increase of diet OM digestibility by 2 units; L2, increase of diet OM digestibility by 4 units.
Environmental impact (carbon footprint) pre and post-action deployment	Pre-mitigtion CF = 5.91 kg CO_{2eq}/kg FPCM Post-L1 = 5.74 kg CO_{2eq}/kg FPCM (-2.9%) Post-L2 = 5.79 kg CO_{2eq}/kg FPCM (-2%)
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Total income Pre-mitigation € 66493 Post-L1 €67400 Post-L2 67400€ Variable costs Pre-mitigation € 46999 Post-L1 € 49236 Post-L2 € 48316 Gross margin Pre-mitigation € 16044 Post-L1 € 14714 (-8%) Post-L2 € 15633 (-3%)

Implemented action 10.2 - Partner responsible: Agris………………………………..

Name of the implemented mitigation action: Improvement of reproduction efficiency

Period	February 2020 – March 2021
Critical issues detected	Low fertility of primiparous ewes – delayed lambings
Objective of the action	Increased fertility and increased milk and meat production with lambings in the optimal period
Description of the action	The activity follows the so-called "Sementusa" protocol. The action involves increasing the reproductive efficiency through veterinary inspection of the flock and selection of the sheep on the basis of the health status (deducible from the analysis of blood samples, feces and ultrasound scanning).
Expected results	Increased fertility, increased milk production due to the reduction of unproductive animals and better lambing period, higher lamb meat production.
	F**arm visits devoted to the acti**on
Date	Activity
January 28, 2020	Ecography of non-lambed (barren) ewes
February 27, 2020	Ram inspection to assess their health status

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available. However, a modeling exercise has been run in order to estimate the impact of the service considering three additive levels of response L1. Increase of the fertility of primiparous; L2. Better concentration of lambings; L3. Optimal level of adult and primiparous ewe feritlity (99%). Technical results are depicted as follows: - increase of milk productin (litri) 6% (L1), 18%(L2), 21%(L3) - increase of lamb production (kg) 37% (L1), 37% (L2), 40%(L3)
Environmental impact (carbon footprint) pre and post-action deployment	This modeling provides the following results: CF Pre-mitigation = 5.91 kg $CO_{2\ eq.}$/kg FPCM Post-level 1 = 5.13 (-13.2%) Post-level 2 = 4.41 kg $CO_{2\ eq.}$/kg FPCM (-25.4%) Post-level 3= 4.34 kg $CO_{2\ eq.}$/kg FPCM (-26.5%).
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	Total income Pre- € 66493 Post-level 1 € 77743 Post-level-2 € 85390 Post-level 3 € 89073 Total variable costs Pre- € 50449 Post-level 1 € 55040 Post-level-2 € 51991 Post-level 3 € 47090 Gross margin Pre- € 16044 Post-level 1 € 22703 (+142%) Post-level-2 € 33399 (+208%) Post-level 3 € 36876 (+229%)

Farm 11 – Pinna

Farm characteristics		Farm 11 – Pinna
Geographical area		Centre
Pedologic substrate		Basaltic
Altitude	m a.s.l.	394
Total Agricultural Area (TAA)	ha	58.5
Utilized Agricultural Area (UAA)	ha	56.1
Natural pasture area	%	86
Annual forage crops	%	14
Heads (number of mature ewes)	N	335
Stocking rate	head ha^{-1}	7.12
Fertility of mature ewe	%	97
Neonatal lamb mortality [(1)]	%	2.08
Milk total annual production	kg FPCM	62,247
Fat and Protein Corrected Milk (FPCM)	kg ewe^{-1} $year^{-1}$	181
Concentrate Intake (kg DM) per FPCM (kg)	kg DM kg $FPCM^{-1}$	0.74
Feed Self-Sufficiency	% (Dry Matter)	56
Work units	N	1
Electricity consumption	kWh 100 kg $FPCM^{-1}$	0.09
Diesel consumption	Lt 100 kg $FPCM^{-1}$	0.01

Hotspot	Farmer perception	Action plan
Low forage quality and productivity of natural pastures	The farmer is aware of the problem and he is inclined to the innovative interventions to improve the productive system efficiency; they need to be driven in this intervention plans	**B1b.** Replacement of degraded natural pasture with improved perennial pasture

Implemented action 11.1 - Partner responsible: CNR-IBE / CNR-ISPAAM

Name of the implemented mitigation action: Replacement of a natural pasture with an improved perennial pasture

Period	From October 2019 (modelization refer to year 2016/2017)
Critical issues detected	Difficulty in the timely establishment of forage crops, with consequent limits in the production of fodder biomass. The main cause is the erratic weather pattern: late breaking rains or extreme rainfall events often prevents timely cultivation. Moreover, cultivation operations overlap with the lambing period, bringing about high workload to the farmers, and sometimes, lower attention to animal needs and their welfare.
Objective of the action	Increase of pasture production, with improvement of the quality. Improvement of environmental performance, with reduction of GHG emissions in relation to the improvement of the digestibility of the fodder biomass offered
Description of the action	Over-seeding of perennial and self-seeding leguminous and graminaceous species. In detail, we proceeded with minimal tillage (harrowing) and sowing the mixture. Crop management involved rotational grazing associated with flail mowing (from 1 to 3 operations per year), with the aim of controlling weeds. Grazing is stopped at flowering which is fundamental to ensure the resilience of the pasture, especially the first year.
Expected results	
	Farm visits devoted to the action
Date	Activity
Luglio 2018	Preliminary assessment of ecological hotspots
October 13, 2018	Monitoring visit
November 25, 2018	Visita di monitoraggio e consegna della semente
April 23, 2019	Monitoring visit
September 30, 2019	Monitoring visit
October 22, 2019	Ploughing
October 23, 2019	Harrowing
October 24, 2019	Sowing of pasture mixture and seed covering

Measured/estimated technical results: forage production, animal production (if applicable) consumptions (feeds, energy, fuel, water)	Data are not yet available
Environmental impact (carbon footprint) pre and post-action deployment	
Measured/estimated revenues and costs (out-of pocket expenses + machinary depreciation) pre and post-action deployment	

3. Remarks on the mitigation action

Preliminary results of mitigation action in terms of percentage abatement of GWP and % increase of gross margin is depicted in Figure 2.

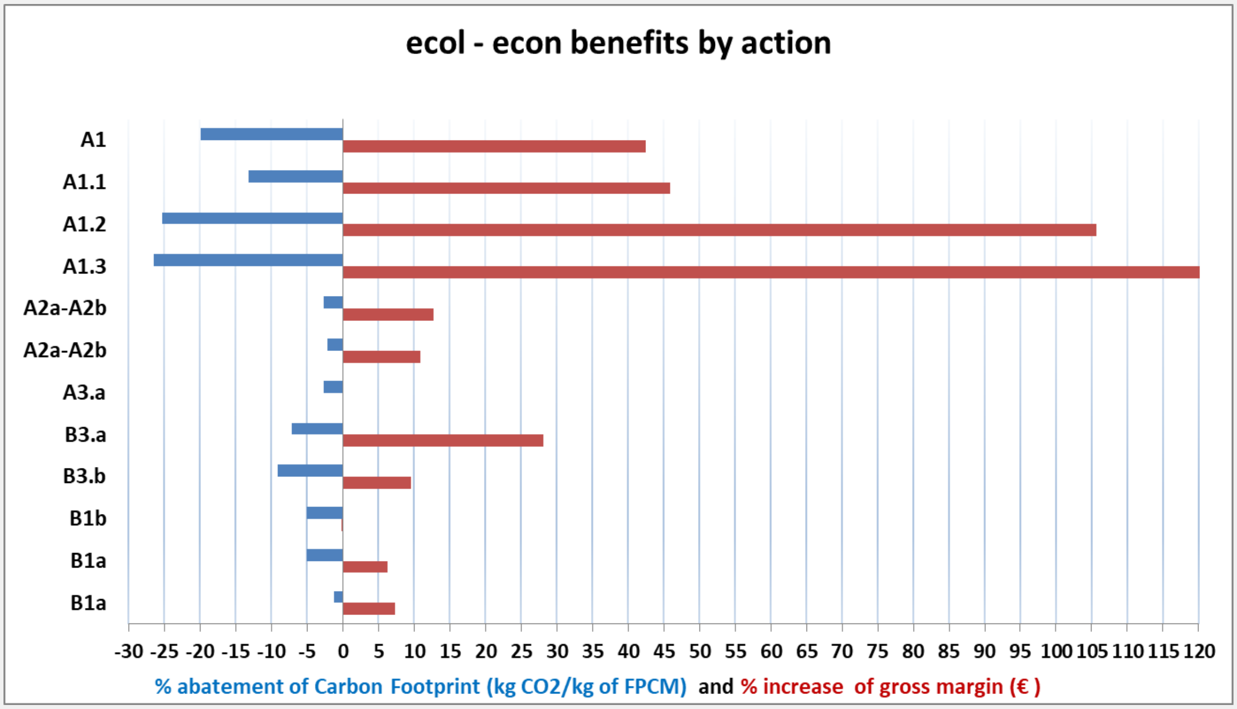


Figure 2 – Preliminary estimated results od some modelled actions. See table 1 for definition

It can be easily appreciated that he abatement related to the action A1 is putatively the most promising and is associated to the highest increase of gross margin, in the best scenarios reaching a level which is twice the actual estimated gain. On average, more probable abatement levels (15-20%) are anyway numerically higher than those achievable by other mitigation actions.

This is probably related to the increase in productivity and hence in farm efficiency due to implementation of this mitigation action. The improvement of milk productivity (A2a-A2b), although relevant for its putative effect on the farm budget, is much less effective in terms of GHG abatement.

Another promising mitigation action belonging to feed production (class B) is the increase of the quality of conserved forages (B3a early cutting and B3b – wrapped haylage) which provides abatement levels between 5 and 10%, much higher than those sourced from the adjustment of sheep diet when fed poor quality forages (A3a). Tuning forage conservation techniques gives an important economic return, particularly if hay is cut earlier than usual (+ 28% of gross margin).

Mitigation actions based on the replacement of natural pasture (B1b) or annual forage crops (B1a, tested in two farms) gives significant abatements, although usually lower than 5% and some relevant benefit from the economic viewpoint.

Interestingly, the introduction of perennial pasture impact markedly on the GWP abatement in terms of ha of invested area as shown in Figure 3.

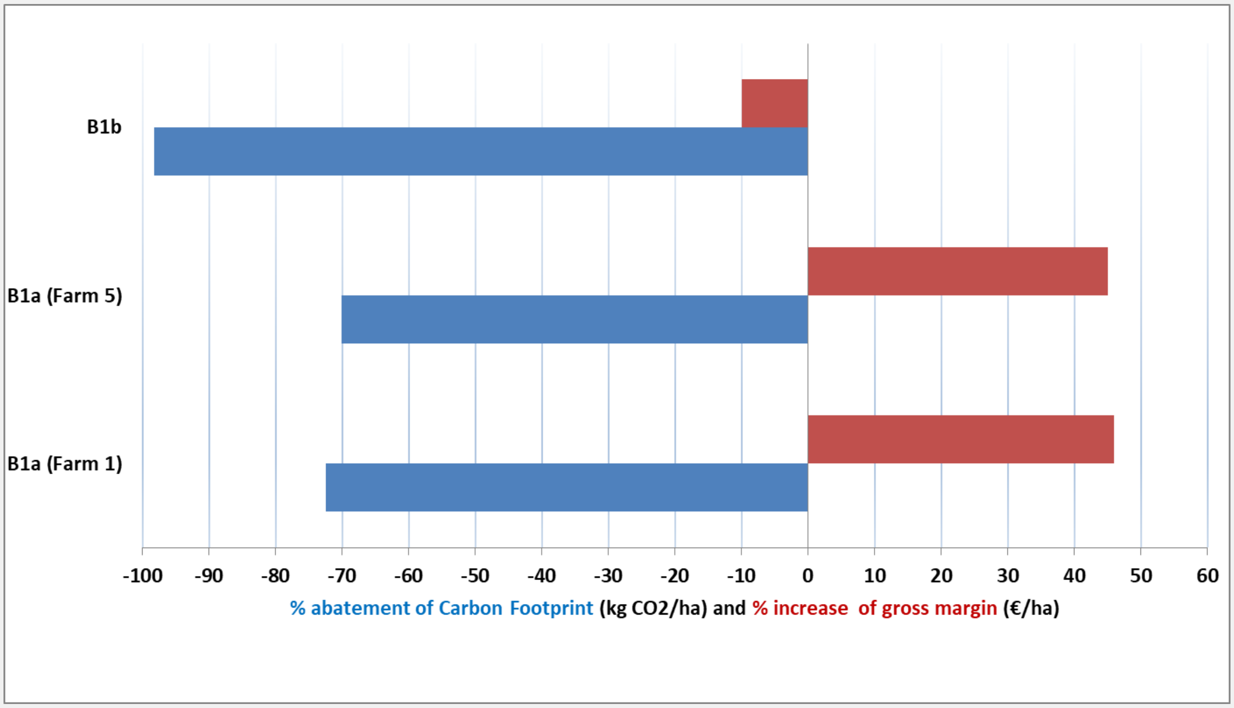


Figure 3. Preliminary estimated results of some modelled actions per ha of farm in which annual forage crops (B1a) or natural pasture are replaced by improved pasture. See table 1 for definition of the actions.

Moreover, the increase of pasture persistence across years allows a significant reduction of labour requirements per unit of land (Figure 3).

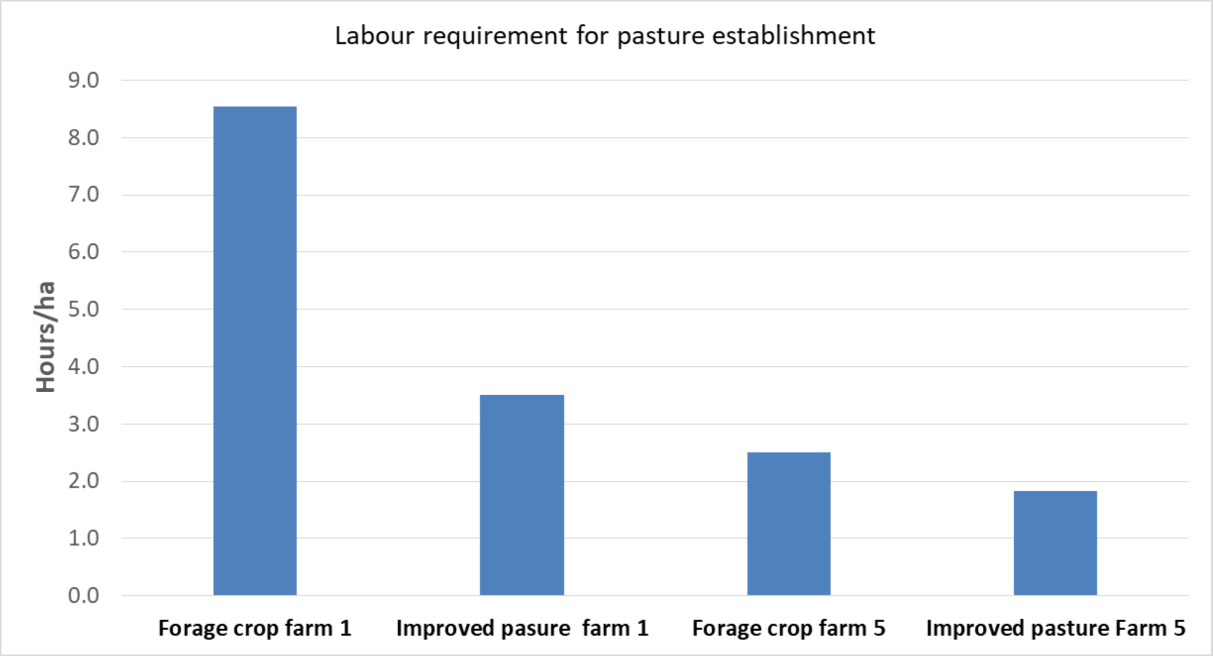


Figure 3. Labour requirements per ha.

These mitigation action may be envisaged in combination in order to multiply their effects at farm scale. On the basis of these preliminary analysis, we could purport as *technically* feasible the target of the project, i.e. to reduce by 20% in 10 years the GHG emissions of sheep farms. In fact, if in 3 years one third of sheep Sardinian sheep farms is able to a substantially increase their reproductive efficiency (12% abatement), 1/3 improve their cultivation efficiency using perennial pastures (abatement 4%) and 1/3 increase their conserved forage quality (8% abatement), on an average this would result in an abatement of 8% of CF at regional scale level. The residual abatement (12% in 7 years) would be possible if marginal improvements of farm efficiency will be adequately disseminated to the rest of farm population. Widespread adoption will depend on farmer perception, public and private consultant support to implementation of mitigation techniques and, of course, supporting policies at regional, national and EU scale.

To sum up, these preliminary results of modelled mitigation actions back the adoption of mitigation strategies and techniques aimed at increasing reproduction efficiency, milk productivity and a more efficient cultivation and conservation of forages in Sardinian sheep farms.

4. Supplementary material

4.1 Soil analyses

To better drive the good practices of land management, fifteen samples of soils were collected from most of the farms subjected to the survey for LCA evaluation. Sample collection followed a standardized protocol. Soil samples were stored and sent to an accredited laboratory. The objective was to evaluate the soil production potential and consequently the sustainability of the proposed measures over time.

The agronomic evaluation of soil analyses is summarized in the following table. For sake of coinciseness, two background colors were used to show the shortage (yellow) and excess (pink/violet) of soil nutrients.

Remarks of soil analyses

Supplementary table 1, with reference to the macroelements indispensable for plant mineral nutrition (N-P-K) shows a good endowment for K, with a relevant number of samples below the optimum range for N and P (27% in both cases).

Among the parameters that are not easily amendable without the adoption of good practices, it can be highlighted that in 33% of cases the organic matter (OM) was below the optimum, while in 47% of cases it showed high values, representative of correct soil management. This aspect is important since soil OM content is the key storage factor of CO_2 in the soil and consequently for its removal from the atmosphere.

Two other important parameters indicating soil fertility are the pH and the Cation Exchange Capacity (CEC). In 27% of soil samples reaction is acidic (pH <6), with low CEC, a situation that represents a condition of poor fertility and unfavorable soil ecosystem for most agricultural crops. In general, there is a low level of CEC in 40% of total samples.

As for the detailed analysis of the exchange complex, it can be noted that in 73% of cases the degree of Basic Saturation is below 100%, being Ca and Mg deficient in 67% and 13% of samples, respectively. A parameter to be kept under strict control is Na level for its known negative effect on soil structure. For this cation there is a deficit in 47% of samples and an excess in 13% of the samples and slightly high level in the remaining part of 40%.

The Mg / K ratio, was found out of the optimum range in 86% of cases, more exactly for 33% samples was too high and for 53% too low.

Finally, among the analyzed microelements, some anomalous situations emerged, such as an excess of Fe and B in 40% and 13% of samples, respectively and a deficit of Cu and Zn in 20% and 7% of samples, respectively.

These aspects must be born in mind to tune the mitigation strategies based on crop management.

Supplementary table1. Soil analyses.

	Northern lowland					Southern lowland						Central hills			C hills Basaltic	N. samples LOW %	N. samples HIGH
Farms/n. sample	1,1 Arca	1,2 Arca	2 Riu	3,1 Manconi	3,2 Manconi	5.1 Cugusi	5.2 Cugusi	5.3 Cugusi	6.1 Ena	6.2 Ena	7 Mulas	8.1 Molozzu	8,2 Molozzu	9 Orritos	10 Mura		
Parent material (class)	F	F	B	D	D	B	B	H	I	I	I	D	D	I	E		
Presence of stones	sensibile	sensibile	trascurabile	tracce	tracce	tracce	tracce	tracce	trascurabile	trascurabile	tracce	sensibile	sensibile	tracce	tracce		
Sand %	51	51	61	61	66	62	64	51	71	72	67	60	61	81	55		
Silt %	26	25	31	21	23	24	20	30	19	20	21	16	16	16	27		
Clay %	23	24	8	18	11	14	16	19	10	8	12	24	23	3	18		
Texture class	FAS	FAS	FS	FS	FS	FS	FS	F	FS	FS	FS	FAS	FAS	SF	FS		
pH	7.6	7.5	5.4	6.3	5.9	6.4	6.3	6.6	7.6	7.7	6.1	5.9	5.6	6.8	5.4	33	
Conductivity (1:2,5) ms/cm	0.352	0.44	0.451	0.093	0.104	0.213	0.197	0.215	0.26	0.355	0.217	0.051	0.069	0.238	0.1		
Total CaCO3 %	17.4	8.9	absent	absent	absent	absent	absent	absent	trace	trace	absent	absent	absent	absent	absent	7	
Active CaCO3 %	4.41	3.1															
Organic matter %	4.47	1.74	4.4	1.94	1.34	1.6	2.48	2.08	1.05	0.68	1.27	2.23	2.61	2.28	3.23	33	47
N-TOT %	0.25	0.119	0.247	0.12	0.086	0.105	0.149	0.127	0.065	0.042	0.082	0.136	0.156	0.138	0.188	27	
P ass ppm	65	65	22	6	7	20	25	13	20	23	16	19	41	7	10	27	
S ass. ppm	10	35	12	5	5	12	12	15	12	20	8	5	5	12	5		
Fe ass. ppm	25.8	35	45.2	55.8	88.4	58.4	40.6	44.8	27.4	24	45.8	126	159.8	47	77		40
Mn ass. ppm	16.8	13.6	21.4	16.4	23.8	26.6	31.8	22.6	7	8	40.2	16.6	26.4	5.6	22		
Cu ass. ppm	1.3	1.3	0.7	1.4	1.2	1.9	1.3	2.2	1.8	2.4	1.4	0.6	0.7	2.6	1.2	20	
Zn ass. ppm	5.4	5.4	2.2	0.8	1.1	5.8	6.6	5.4	2.4	2.4	6.4	1.4	1.7	6.4	5.8	7	
B ass. ppm	1.78	1.78	0.8	0.42	0.38	0.66	0.82	1.1	0.46	0.6	0.6	0.4	0.46	0.52	0.96		13
Ca exc. ppm	3500	3300	620	1720	1080	1000	940	1820	1200	1000	860	2020	1420	540	560		
Mg exc. ppm	118	86	116	620	340	200	190	400	90	92	178	980	900	142	154		
K exc. ppm	418	461	239	289	399	399	282	145	500	598	55	180	180	379	418	6.7	
Na exc. ppm	124	221	108	361	281	87	83	166	172	195	85	200	177	76	170	27	7
CEC* meq/100 g	20.09	19.36	7.47	17.91	11.72	10.56	10.43	15.68	8.78	8.15	9.69	22.6	18.9	5.93	7.97	40	
Ca% CEC	87.1	85.2	41.4	48	46.1	47.3	45.1	58	68.4	61.4	44.4	45.4	37.6	45.5	35.1	67	
Mg % CEC	4.9	3.7	13	28.9	24.1	15.8	15.1	21.2	8.5	9.4	15.3	36.7	39.7	19.9	16.1	13	
K % CEC	5.3	6.1	8.2	4.1	8.7	9.7	6.9	2.4	14.6	18.8	1.4	2.1	2.4	16.4	13.4		
Na % CEC	2.7	5	6.3	8.8	10.4	3.6	3.5	4.6	8.5	10.4	3.8	3.9	4.1	5.6	9.3	47	13
Base saturat. %	100	100	68.9	89.8	89.3	76.4	70.6	86.2	100	100	64.9	88.1	83.8	87.4	73.9	73	
Ratio Mg/K	0.92	0.61	1.59	6.99	2.77	1.64	2.19	9	0.59	0.5	10.57	17.76	16.3	1.22	1.2	53	33

* Cation exchange capacity

Legenda: yellow background indicates very low levels (deficit). Pink background very high levels (excess)

4.2 Feedstuff analyses

Feeding is in theory the management that could have the higher mitigation impact on the sheep farm carbon footprint since enteric CH_4 emission is the main hotspot according to LCA, and its emission level is related to sheep diet. A better knowledge of feedstuff characteristics could favour a better balancing between animal requirements and nutrient allowances, improving the efficiency of feeding. Morevover, the shortage of some macro-nutrients such as Crude Protein (CP) or Neutral Detergent Fiber (NDF) or their excess can hinder sheep productivity in terms of milk yield and increase waste of nutrients to the environment. Finally, low levels of micronutrients such as Se and Zn can bring about low reproductive efficiency. Copper excess can be also a problem, since Sarda sheep are sensitive to Cu toxicity. For these reasons, a survey was run in parallel with the demonstration activities in the 10 farms initially chosen for the demonstration of mitigation activities, with the aim to evaluate the nutritive value of the feedstuffs used on farm: supplements (hay and concentrates) and grazed herbage. A protocol was devised and samples were gathered, tagged, stored and then sent to accredited laboratories of Agris and "Istituto Zooprofilattico Sperimentale della Sardegna (IZPS) " a regional Institute aimed , among others, at assessing the health of livestock by focused determinations of biomarkers in several specimens such as feedstuffs. This Institute was responsible for the analyses of micronutrient in feedstuffs described hereunder.For sake of simplicity and coinciseness, in the following tables excess and deficit of nutrients will be marked by different colours (red deficit, violet excess) to highlight possible shortcomings of an extensive use of unbalanced feedstuffs in sheep diet. These data are currently under a completion phase (e.g. macro-elements analyses of herbage samples are lacking) but are already anticipated to the farmers in order to adjust sheep diet accordingly.

Remarks on feedstuff analysis

As shown in Supplementary table 2, a wide array of concentrates are used in Sardinian sheep farms, ranging from purchased cereal grains and legume seeds to different commercial pelleted concentrates, which are often combined in sheep daily ration. Interestingly, some commercial concentrate show a high level of starch, which can sometimes brings about milk fat depression as observed in farm 10. Most of commercial concentrates have a good content of Ca and P and macro-minerals but sometimes their content in Cu is above the toxicity limit for sheep (10 mg/d), which is also the case for soybean meal and faba bean. However, this could be compensated by the low level in the forages (see below). The level of Se in grains is very low or nil.

A high proportion of hays have low levels of CP (<7 % DM) and high level of NDF (>70 % DM) (Supplementary table 3). Basically, only lucerne hay has an adequate nutritive value. This is one of the most important shortcomings of sheep farming in Sardinia, since the low quality of conserved forage results in high level of concentrates in sheep diet, when pasture availability is low. Conserved forages are also usually poor of macro and micro minerals, except for Mn.

In contrast, grazed herbage (Supplementary table 4) has a very high nutritive value, due to the high content of CP and cell content and the low conten of fibre. Unfortunately, the level of micro-minerals is often deficient for Zn, Cu, Se and Mo, with a couple of exception for Cu, high in Sulla and some mixed forage crops containing legumes.

Overall, the level of Se is very low in all feeds, except some commercial pellet. This suggests the need of a targeted Se and vitamine E supplementation, particularly during summer and autumn in order to prevent lamb myodistrophy. Vitamine E has in fact a synergic role in the prevention of this pathology.

Targeted supplementation of macronutrients and macro- and micro-minerals and vitamins in sheep diets can boost reproduction and production efficiency and represent a key tool to decrease emission intensity of sheep farms.

Supplementary table 2. Feedstuff analyses –Concentrates

Farm No.	Feed	CP	NDF	Starch	EE	Ca	Mg	K	P	S	Fe	Na	Mn	Co	Zn	Cu	Se	Mo
		% DM	% DM	% DM	% DM	% DM	% DM	% DM	% DM	% DM	mg/Kg	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM
1	Concentrate TLR17	19.09	20.67	33.94	3.58	2.00	0.28	1.13	0.64	0.29	313	5253	102	0.29	170	8	0.5	1.5
1	Barley	12.03	28.21	49.58	1.66	0.19	0.13	0.65	0.45	0.13	165	355	25	0.04	27	5	**0.0**	0.8
2	Corn	12.63	10.59	64.21	2.98	0.03	0.13	0.59	0.33	0.09	73.3	74	8	0.08	18	4	0.1	1.6
5	Lactation pell.	19.65	20.78	36.29	2.73	1.28	0.29	1.01	0.67	0.2	655	6274	58	0.23	56	10	0.2	0.9
5	Dehy beet pulp	9.44	51.09	10.94	0.56	0.93	0.28	0.32	0.08	0.12	396	878	84	0.09	8	4	0.1	0.1
5	Barley	12.81	26.17	48.48	1.43	0.12	0.13	0.52	0.37	0.11	1590	410	20	0.08	61	5	0.0	0.1
5	Mix corn-faba bean	18.81	13.29	56.70	2.35	0.04	0.13	0.83	0.43	0.12	105	90	8	0.15	25	4	0.1	0.9
5	Oats	12.65	31.45	39.55	4.44	0.13	0.10	0.38	0.32	0.16	336	322	21	0.06	51	4	0.1	0.3
6	Lactation pell.	19.12	24.13	32.08	3.51	1.15	0.31	1.19	0.73	0.23	323	7754	126	0.25	105	11	0.5	1.0
6	Barley	11.00	24.17	50.13	1.58	0.20	0.21	0.76	0.49	0.13	526	594	18	0.06	28	5	0.5	1.1
7	Lactation pell.	18.59	22.59	30.71	3.62	1.76	0.29	1.15	0.67	0.29	462	5924	99	0.36	158	8	**0.6**	1.4
7	High protein nucleus	22.70	31.96	16.43	3.37	2.04	0.35	1.46	0.67	0.29	448	6175	120	0.26	131	11	0.4	1.9
7	Corn meal	8.77	9.65	68.46	3.65	0.11	0.12	0.45	0.31	0.08	78	189	8	0.02	24	2	0.1	0.3
7	Wheat meal	12.69	16.49	63.02	2.11	0.07	0.09	0.44	0.25	0.11	140	158	65	0.08	42	3	**0.0**	0.1
7	Faba bean meal	26.29	19.37	36.20	1.12	0.18	0.15	1.35	0.56	0.15	209	252	17	0.45	59	**13**	0.1	3.7
7	Soybean meal	47.44	13.94	8.29	0.64	0.35	0.31	2.49	0.65	0.32	161	< 50.00	48	0.14	41	**13**	0.4	6.1
7	Dehy beet pulp	9.49	46.79	11.63	0.55	0.64	0.26	0.44	0.08	0.11	855	822	77	0.14	11	3	0.1	0.2
8	Mix pell. and corn	18.98	17.82	**41.69**	3.19	1.70	0.29	1.03	0.61	0.27	227	2026	79	0.17	90	**12**	0.3	1.3
9	Mix pell and beet pulp	15.90	29.74	26.11	3.47	1.71	0.41	1.14	0.73	0.23	523	3529	101	0.38	121	**12**	0.2	0.7
10	Pell. Conc. for lambs	10.68	22.63	**40.13**	2.52	0.52	0.05	0.20	0.13	0.05	69.5	2254	67	0.11	72	7	0.1	1.3
10	Lactation pell.	13.88	19.76	**42.55**	3.92	1.05	0.24	1.15	0.69	0.16	307	2802	58	0.10	67	6	0.1	0.8
11	Lactation pellet	17.49	24.40	32.94	3.90	1.38	0.29	1.03	0.68	0.24	180	5178	105	0.40	158	10	0.5	0.8

Violet letters indicate excess whereas red letters deficit of a nutrient

Supplementary table 3. Feedstuff analyses –Conserved forages

Farm n.	Feed	SS	CP	NDF	ADF	ADL	IVDMD	Ca	Mg	K	P	S	Fe	Na	Mn	Co	Zn	Cu	Se	Mo
		%	% DM	% DM	% DM	% DM	% DM	% DM	% DM	% DM	% DM	% DM	mg/kg DM	mg/kg DM	mg/kg DM	mg/kg DM	mg/kg DM	mg/kg DM	mg/kg DM	mg/kg DM
1	Lucerne hay	85.48	19.83	52.36	35.89	8.24	57.71	2.34	0.33	1.92	0.36	0.4	922	2919	**9**	**0.03**	**14**	**5.3**	**0.01**	**0.32**
1	Mixed hay	88.15	8.62	65.30	42.73	8.00	**47.58**	2.16	0.20	1.75	0.36	0.17	344	3886	28	0.08	**14**	**3.2**	**0.02**	2.51
5	Grass hay	89.76	**5.40**	**74.75**	41.88	4.16	**43.18**	0.61	0.16	0.94	0.27	0.17	470	6260	18	**0.05**	**92**	**2.0**	**0.03**	**0.09**
5	Grass hay	87.09	**4.37**	**70.29**	41.53	4.66	**42.66**	0.86	0.12	1.73	0.33	0.14	274	2990	21	**0.04**	**13**	**3.6**	**0.01**	**0.80**
5	Lucerne hay	83.69	17.35	51.52	37.10	7.68	60.73	1.36	0.18	3.32	0.35	0.28	352	571	20	0.13	**16**	**5.4**	**0.08**	**0.77**
6	Grass hay	81.85	**4.57**	**80.38**	45.56	5.22	**32.15**	0.36	0.15	1.49	0.33	0.12	455	2944	14	**0.03**	**7**	**1.8**	**0.06**	**1.68**
7	Triticale silage	27.31	7.58	64.04	38.41	4.58	**44.89**	0.54	0.22	1.37	0.31	0.16	299	1091	27	**0.03**	**13**	**1.5**	**0.01**	**0.05**
7	Grass hay	83.58	**4.22**	**71.55**	41.03	4.30	**43.54**	0.54	0.17	1.10	0.22	0.13	306	6463	99	0.11	**19**	**2.2**	**0.03**	**0.12**
8	Grass hay	87.85	**4.69**	**76.39**	44.77	5.17	**34.95**	0.74	0.26	1.01	0.29	0.12	1110	2948	65	0.07	**12**	**2.2**	**0.01**	**0.13**
9	Grass hay	88.76	**4.74**	**76.19**	44.71	5.16	**35.40**								161	0.23	**12**	**2.5**	**0.02**	**0.12**
10	Pray hay	83.87	7.45	65.17	38.02	5.51	**48.08**	0.85	0.26	0.95	0.22	0.18	2039	5120	148	0.38	**20**	**3.4**	**0.02**	**0.40**
10	Mixed hay	80.17	6.96	68.05	41.47	5.84	**47.79**	0.81	0.19	2.02	0.32	0.16	436	2568	48	0.09	**11**	**3.4**	**0.01**	**0.37**
11	Mixed hay	92.02	**3.29**	69.87	40.68	3.01		0.60	0.12	1.71	0.17	0.14	169	3708	46	**0.06**	**8**	**2.2**	**0.03**	**0.68**

Violet letters indicate excess whereas red letters deficit of a nutrient

Supplementary table 4. Feedstuff analyses – Grazed herbage

Farm N.	Date	Feed	DM	OM	CP	NDF	ADF	ADL	IVDMD	Mn	Co	Zn	Cu	Se	Mo
			%	% DM	% DM	% DM	% DM	% DM	%	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM	mg/Kg DM
1	27/2/19	Improved pasture mix	20.40	90.44	23.63	29.71	13.33	1.52	86.02	63.3	0.14	**23**	**6.4**	**0.02**	**1.3**
2	28/3/19	Improved pasture mix	25.94	92.52	10.68	33.38	15.03	1.23	86.86	151.0	0.22	**18**	**4.5**	**0.02**	**0.2**
5	17/4/19	Ryegrass and chicory	18.11	88.57	14.69	41.69	19.11	0.94	82.46	34.4	0.07	**20**	**5.2**	**0.04**	**1.5**
5	17/4/19	Sulla	14.75	89.36	18.10	37.22	19.93	6.03	78.85	69.7	0.23	**29**	**12.0**	0.15	**0.2**
5	6/3/19	Ryegrass	17.02	85.31	19.21	40.72	18.10	1.12	84.42	113.0	0.30	**27**	**6.4**	**0.06**	**1.7**
5	6/3/19	Natural pasture	16.86	87.19	18.86	41.81	20.58	3.08	75.93	70.6	0.43	**41**	8.2	**0.03**	**0.5**
6	28/3/19	Ryegrass-colver	17.23	87.99	22.46	40.86	16.95	2.44	83.75	41.4	0.18	**26**	**11.1**	0.31	**2.5**
6	28/3/19	Improved pasture	13.12	86.13	29.73	31.10	15.55	1.83	83.28	56.7	0.25	**42**	**15.4**	0.30	8.6
7	17/4/19	Clover-Ryegrass-Chicory	15.44	80.70	21.57	36.79	17.62	2.85	80.29	107.0	1.24	**49**	**12.0**	**0.07**	**0.7**
7	17/4/19	Sulla	16.87	85.95	14.29	33.61	17.90	5.33	76.09	69.3	0.82	**32**	9.9	**0.04**	**0.2**
7	6/3/19	Ryegrass	18.38	84.33	19.86	38.30	17.19	1.47	85.92	93.0	0.61	**41**	9.5	**0.05**	**0.8**
8	20/2/19	Natural pasture	14.74	87.58	27.75	44.84	18.93	1.83	89.03	76.0	0.12	**34**	7.6	**0.01**	**0.5**
9	20/2/19	Ryegrass	22.97	87.77	15.54	44.36	20.72	1.87	82.34	153.0	0.19	**15**	**4.5**	**0.02**	**0.9**
10	16/4/19	Natural pasture	18.92	90.27	19.93	44.50	19.93	2.43	78.34	119.0	0.51	**34**	8.0	**0.03**	**0.4**
10	20/3/19	Natural pasture	24.67	90.39	24.73	48.07	19.94	2.43	79.73	97.2	0.27	**34**	7.7	**0.03**	**0.2**
11	20/3/19	Natural pasture	25.41	89.41	14.40	44.79	21.72	2.09	74.97	54.8	0.20	**20**	**6.0**	**0.03**	**0.2**

Violet letters indicate excess whereas red letters deficit of a nutrient