SUSTAINABLE LAMB MEAT PRODUCTION FOR EUROPE

ERA-NET SusAn Funded Project
Supporting
"Holistic Production to Reduce the Ecological Footprint of Meat"

ERA-NET SUSAN
EUROPEAN RESEARCH AREA ON SUSTAINABLE ANIMAL PRODUCTION

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Introduction

Sheep production is a crucial sector of human activity. There are an estimated 1 billion sheep in the world. The major sheep farming areas are located within the latitudes 35-55 degree north in Europe and Asia and between 30-45 degree south in South America, Australia and New Zealand. There are three major management systems for sheep production that exist in the world; extensive production for wool and meat, intensive dairy production and traditional pastoralism. While regarded by some experts as the healthy red meat option, the current world consumption of sheep meat stands at about 2.5 kg per person annually out of an annual meat consumption of 41.6 kg per person[*1].

In the European Union (EU), sheep meat production is predominantly based on extensive or semi-extensive grazing systems. The level of self-sufficiency in the EU for this sector stands at approximately 77% and holds great importance as a major source of livelihood for the small farmer and the landless in rural communities while also contributing to peri-urban and urban households by providing food, clothing, income and other socio-cultural wealth. Consequently, increasing sheep meat production without causing environmental damage, as well as improving its quality to make sheep meat more healthy, attractive and sustainable is essential to guaranteeing a decent level of performance for sheep producers.

"The decline of the sheep industry in Europe would see extensive landscapes with their human populations and environment adversely affected, leading to the loss of a culture that has survived unchanged for millennia".

The interaction of lamb farming systems with the environment is acquiring growing importance in the EU policy agenda, imposing a certain pressure over the most intensive systems while opening a new space for more extensive ones which could provide additional ecosystem services like biodiversity, climate regulation, etc.. In parallel, consumer awareness about quality and sustainability of the production cycle of animal food products is also increasing. There are also, a set of quality brands associated with lamb meat, which are intended not only to certify its quality but also to increase the producers incomes, given that their interests converge with the interests of the modern consumer who seeks quality and safety, animal welfare, environmental protection, etc. guarantees. In fact, consumers increasingly demand food associated with sustainable production systems that contribute to the conservation of biodiversity while confronting climate change by controlling GHG emissions, etc. The EU great diversity of agrarian systems associated with semi-natural habitats and rural landscapes of recognized environmental value is also essential for other productive systems, such as tourism. However, these landscapes are not static, they are under constant evolution and they often derive from livestock systems currently in a recessive stage whose consequences go beyond the merely productive, like increased bigger fire risks, spread of pests over more homogeneous landscapes, loss of traditional ecological knowledge, and alike. . Among the tools to revalue the livestock sector are to improve our understanding of the ecological footprint elements of the different production systems and their capacity to provide key ecosystem services, such as climate change regulation, biodiversity and conservation of natural resources.

"EcoLamb"

The Ecolamb Project aimed to assess the sustainability of diverse sheep production systems in Europe and Turkey, focusing on the ecological footprint, animal welfare aspects and nutritional value of lamb meat with the goal to understand the potential future barriers that limit the innovative capacity and development of the sector.

Despite a significant hurdle in the shape of a global pandemic, our 36 month project achieved a significant quantity of its objectives to assist the farmer improve the lamb meat sector in Europe. The trans-national Project Consortium with research and industry stakeholders from 6 countries made up of Italy, Portugal, Slovenia, Spain, Germany and Turkey analysed resource-efficient, competitive and healthy lamb production models and have made their recommendations within this booklet. The Ecolamb consortium felt that while addressing the sustainability pillars aimed to maintain the rural landscapes and livelihoods throughout the European Union, researchers needed to prioritise natural resource management a little higher on the ladder as we face a more rapid climate change scenario than was originally forecast. Our project was determined to ascertain which of the production systems left a smaller ecologic footprint on the EU farm paddock to produce a kilogram of lamb meat; and to do this without compromising any nutritional value for a healthy existence.

Although sheep meat has a small share (~1.5%) of the total meat production in the EU, sheep farming is of great importance to rural livelihood and the environment. Lamb production across EU shows a great array of variability, with systems adapted to produce meat in almost every context: from the very extensive systems in the mountain areas where grass growth is ensured and animals graze and grow without any specific shelter, to the most intensive systems in dry farm cereal steppes where grain supplementation is always required. All these production systems have adapted themselves to the opportunities and constraints placed on them by the location (weather, altitude, degree of isolation, etc.) and the availability of natural resources, where they have been established and developed. Our project results have

shown that an acceptable quality of lamb meat production is possible in any of those systems, albeit with some variability in performance, profitability and carcass characteristics. The impact of these different systems on biological diversity and their ecological footprint must be interpreted sparingly, because when the environment supporting the lamb production system has been modified by human intervention, the real impact assessment is an extremely complex task.

"Enhancing the quality of lamb meat of local breeds is essential to ensure both profitability for sheep producers and the conservation of endangered breeds".

A better understanding of small ruminant breeds across Europe and their potential for future food security by utilising different types of pasturelands is also crucial, especially for their ability to use remote and marginal areas with geographic handicaps which limit other productive activities while they can maintain more diverse and resilient territories. EU policy has already addressed the importance of supporting small households in marginal territories, but this project confirms their potential future role and the clear need of stronger support for the farmers who face so many difficulties to survive and produce healthy and unique food based solely on natural resources.

In addition, the need for further EU support of local agri-food systems to ensure future food security at EU, national and local level has often been raised as a strategic limitation which should also be addressed fairly urgently. The current pandemic situation has confirmed that such need is in fact crucial at international level once we are aware about the vulnerability of those countries whose agri-food systems have drastically declined while other productive activities (including some with higher ecological footprint) were prioritized. Supporting all aspects of local livestock production has to be a priority because progressive animal production systems are required to provide a wider range of additional ecosystem services which could provide an additional value to the local producer by acknowledging their cultural singularity, environmental contribution, support to other productive systems, etc. In the case of small ruminants, the range of crucial ecosystem services which can be obtained from areas managed with them include reduction of fire risk by controlling the proliferation of shrubby vegetation (particularly in the Mediterranean Basin), the conservation of pasturelands which are safe carbon sinks and hold unique biodiversity and the conservation of diverse landscapes which help to control the spread of animal and plant diseases. As such small ruminant production has a very important role in improving rural livelihoods.

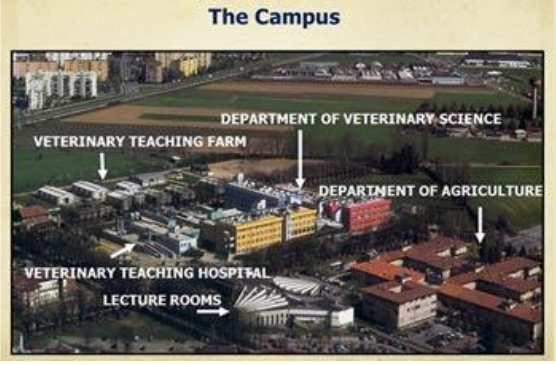
We hope that the outcomes and initiatives resulting from the EcoLamb project will be used and further developed by stakeholders to make visible and value the importance of these productive activities, promote changes in farm management to improve their efficiency and reduce their ecological footprint, as well as promote marketing and processing of lamb meat to make all aspects of the European sheep industry more sustainable.

Consortium Partners

Italy – The University of Torino (Project Coordinator)

Established in 1404, is one of the most ancient and prestigious Universities in Italy. It hosts about 70,000 students, 4,000 academic, administrative and technical staff and 12.300 graduate students. In different areas in Torino and key places in the Piedmont Region. UniTo can be considered a "city-within-a-city", promoting culture and producing research, innovation, training and employment. UniTo carries out scientific research and offers over 150 undergraduate and postgraduate degree courses in almost every field of study.

The Italian Project team (the project coordinator) is lead by Mario Baratta in the Dept. of Veterinary and Agricultural



Sciences. The other members are Luca Battaglini, Elisabetta Macchi, Silvia Miretti, Francesco Chiesa, Alberto Brugiapaglia, Giovanni Perona and Sinan Ogun.

Case Study Farm/s and Breed of Sheep for Italy:

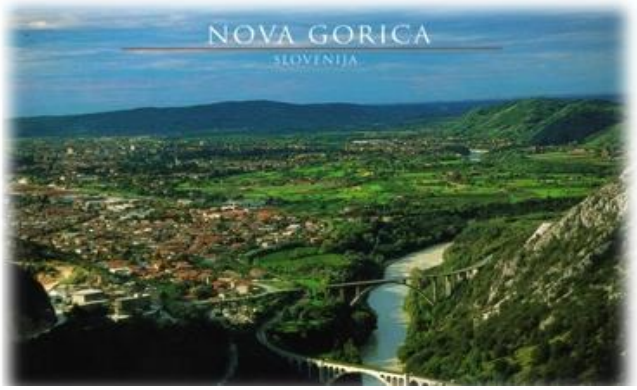
The Stura Valley in the **Alpine** bio-region has always been a strategic link between Italy and France, and it has historically represented one of the ancient "Salt Routes". Agriculture has played a key role in the local economy for a very long time. Grasslands and extensive rangelands typical of these marginal areas represented a traditional feed source for low-intensity livestock systems. Sheep breeding has always been one of the most important rural activities of this valley. The autochthonous sheep breed of the Stura di Demonte valley is the **Sambucana**, locally known as "**Demontina**". Its name origins from Sambuco, a small village located in the upper part of the valley. Its origin is still unclear, but it is known that the Sambucana sheep has been introduced in the territory during the 18th century. Rearing this sheep for hundreds of years in poor, rocky and marginal pastures with harsh climate conditions contributed to its successful adaptation to the unfavorable environment. Nowadays, shepherds appreciate the Sambucana especially for its rusticity, agility and robustness. From spring to late autumn sheep flocks are reared in alpine pastures (1,500-2,500 m a.s.l.), without shelters for night or frequent off-season snowfalls. This sheep is able to pass steep slopes through paths carved into the rock and to reach the highest pastures. During winter they are stabled and fed with local hay only. The farm is located in Municipality of Pietraporzio, hamlet of Pontebernardo (1312 m a.s.l.) and it rears only sheep of the Sambucana breed. The farm hosts an average of 200 animals, and is a part of the wider flock of the Escaroun consortium. The production is multi purpose, lamb rearing for meat but also wool and cheese production, limited to just a few months per year. Sheep graze on the areas surrounding the farm in spring and autumn, and on alpine pastures in summer at 2000-2400 m.a.s.l. During this period, animals leave their enclosures guided by dogs and shepherds. Here they graze surrounded by electrified fences, which also serve as shelter against wolves during night time. Before alpine transhumance begins, in January and May, the shearing is carried out on the farm. In winter sheep live in stables and receive local hay, with no supplementation except for minerals. There is one stable specifically dedicated to sheep and lambs for weaning and a small stall for weaned lambs and heavy lambs, called "Tardoun". Three people are employed throughout the year in the winter season, two during the Alpine pasture period. Farmers always use natural service, with rams selected from Pontebernardo Rams Center. Parturitions gather mostly from late September to late October, sometimes in May. Lambs are weaned naturally when they are 3 months old. Every year 10-15% of ewes are changed with an internal

restock. The prolificity is around 147%. The Sambucana breed is classified as a medium-large breed: adult weight is 85-90 kg in males and 65-70 kg in females. The average birth weight of lambs is about 5 kg. Ewes give birth for the first time when they reach 14-15 months of age. The head is light, hornless, with horizontal ears; the legs are thin and firm, the back is large with good muscular development. The fleece is cream-white (Ref *2).

The second farm: SDSV is the Teaching Farm of the Faculty of Veterinary Medicine - Uni. of Torino and is classified to be in the **Continental** bio-region. It is located in the city of Grugliasco, in close proximity to the Piedmontese regional capital. The Zootechnics and Food Hygiene departments operate with five different types of livestock husbandry, including cattle, pigs, sheep, horses and poultry. It also comprises a feed mill, a quarantine barn, an experimental animal room and a surgery room specifically dedicated to research activities. Animals admitted to the farm are used for teaching purposes in the courses of Veterinary Medicine and Animal Production Science. Students take part in the farm activities since their first year, interacting with the animals during the course of practical exercises and training sessions. Attached to the farm is the Teaching Slaughterhouse, a CE health mark approved structure for cattle, horses, pigs and small ruminants with didactic and experimental purposes conducted by Teachers from the University of Torino as well as other public and private institutions. It also provides, apart from food products, anatomical specimens, organs and tissues for practical sessions. For the purposes of the EcoLamb project the facility is housing the **Biellese** breed. The farm has vast areas of land used for the self-handling of hay and forages, fenced areas operating as paddocks and pastures for small ruminants. All animals reared in the structure are controlled by veterinarians and animal technicians, who are in charge of management, structural maintenance, animal nutrition and health care. The farming is semi-intensive in nature: animals spend autumn and winter months in a stable connected to an external paddock, while spring and summer months are spent on pasture. The faculty pasture covers an area of 1500 square meters and features a large shelter equipped with feeding troughs. Animals receive feed and hay, while during hot months they graze. Breeding is managed according to natural photoperiodism: they take place during September / October through natural serving, and parturitions concentrate at the beginning of spring. Lambs are weaned naturally and remain under their mother until they are 3 months old. All animals used for reproduction have been selected for the Scrapie resistance gene. Pharmacological treatments, such as vaccinations and anti-parasitic treatments, and obstetric examinations for the evaluation of pregnancies are carried out by faculty veterinarians and students during the course of practical sessions. The **Biellese** breed, genetically and morphologically similar to the **Bergamasca**, originated in Piedmont. It is predominantly reared in the provinces of Torino, Vercelli and Cuneo. This breed has a prevalent capacity for meat production, but its capacity for the production of milk and wool, utilized in the past for the packaging of mattresses, stuffing and carpets shouldn't be completely overlooked. Today, however, farmers who choose the breed mainly for meat production, specifically weathers. The Biellese is classified as a large breed, with an average adult weight of over 110 Kg in males and 80 kg in females. Males present a height at the withers of 100 cm while females around 85 cm. The head is hornless, with long pendulous ears; the torso is long and deep, the rump is large and the abdomen voluminous. The fleece is white and covers the neck as well as the legs up to the hock. The skin is clear and the hooves are amber-yellow. The average birth weight of the lambs varies between 4.5 and 5 kg, and they reach 30 kg within 90 days. The prolificacy is around 140%. The SDSV farm hosts an average of 45 animals, annually recorded during the months of March-April. On average it hosts 30 breeding ewes, with a restock of 6 animals/year, which means that females are replaced when they are about 5 years old. The price paid for the rams is about 250 euros/animal, while ewes are around 200 euros. Animals are divided into two groups, one seasonal and the other counter-seasonal. Heat is synchronized through hormone treatments and natural service is always utilized, according to a 1:10 ratio of males/females. The farm produces different types of products: the milk lamb, slaughtered at 50 days with a weight that exceeds 15 kg; the heavy lamb at 6 months around 45 kg LW, and the castrated weathers at 12 months with a weight of about 60 kg. Animals exceeding the restock, both males and females, are intended for slaughter. The commercial value of the milk lamb is 12 euros/kg, the heavy lamb of 6 months and the weathers reach 5 euros/kg, while the price for ewes drops to 3 euros/kg.

Slovenia – The University of Nova Gorica

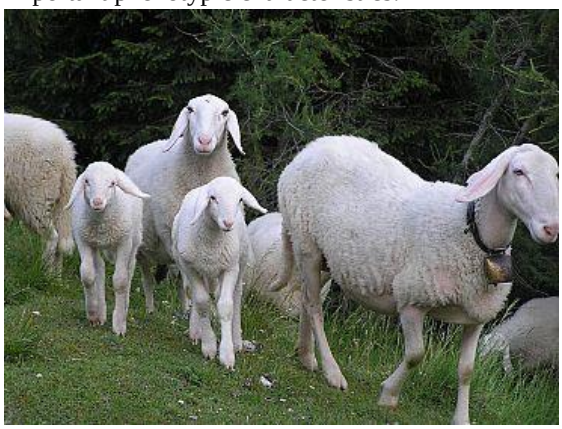
In 2020, the University of Nova Gorica celebrated its 25th anniversary. The School of Environmental Sciences, founded in Sept 1995 was the first international postgraduate school in Slovenia and the predecessor of the Uni. of Nova Gorica.. The educational activities were implemented within five schools, one professional college, and an academy of the arts.



The research activities took place in six centres and four laboratories. The University of Nova Gorica is becoming an increasingly internationally oriented institution. In 2019, foreign students from 48 different countries represented 54% of the student population. University is also becoming an attractive venue for foreign scientists and professors. In 2019 the number of experts from other countries had increased considerably accounting for approximately 25% of all employees. The project team in Slovenia consisted of Tanja Peric and Martina Bergant.

Case Study Farm/s and Breed of Sheep for Slovenia: Alpine Region

The case study farm representing the Slovenian lamb production system is a farm located in the Alpine bioregion at an altitude of 211m.a.s.l. Characteristic for the region, the farm runs an extensive production system rearing one of the typical and autochthonous Slovenian sheep breed - the Jezersko-Solčava. The farm flock is around 35 adult females and the natural insemination is carried out by 2 rams. Primarily used for meat, the sheeps wool is also valued by the farmer and the consumer. The breed was formed by crossing a primitive domestic white wool sheep with a Bergamo and Padua breeds. Jezersko-Solčava has the characteristic convex nasal profile from the Bergamo breed and has inherited the wool quality from the Paduan genetics. The breed is widespread throughout Slovenia, and most herds are still in its original local area in Jezersko and in the vicinity of Solčava and Luč in the Upper Savinja Valley. The average flock size is 30 to 40 animals, only a few producers have more than 100 animals. The most important breeding goal and herd management starategy is to maintain the size of the breeding population and important phenotypic characteristics.



The **Jezersko-Solčava** breed is hornless and mostly white, but rarely black, dark brown or a mixture of both. In white sheep, a dark colored spot around the eyes (“glasses”) or under the eyes (“tears”) and on the tips of the ears is desirable. The breed is characterized by a convex nasal profile of the head. The animals are of medium size, have large drooping ears and a long, woolly tail that extends below the hocks. Her back is strong and long, her legs also firm and long, which allows her to walk well on steep mountain pastures. The rams of the Jezersko-Solčava breed reach a height of more than 70 cm, the females slightly smaller. The body weight of rams is around 90 kg., and ewes around 70 kg. The characteristics of the breed are light lambs and good twining. Sheep have well-defined maternal traits and take good care of offspring. Due to good fertility, the breed is very suitable for economic crossbreeding with meat breeds. Sexual maturity for both sexes is from 6 months onwards. Whilst the main breeding purpose is meat, their quality wool is also regaining importance. The diameter of the Jezersko-Solčava wool fiber is between 25 to 35 microns, which places it in the class of medium-fine wool. Fringed wool may be present in the fleece; as an undesirable trait it eliminated by the farmer through selection Ref *1.

Spain – There were 3 Spanish partners that took part in the EcoLamb project:

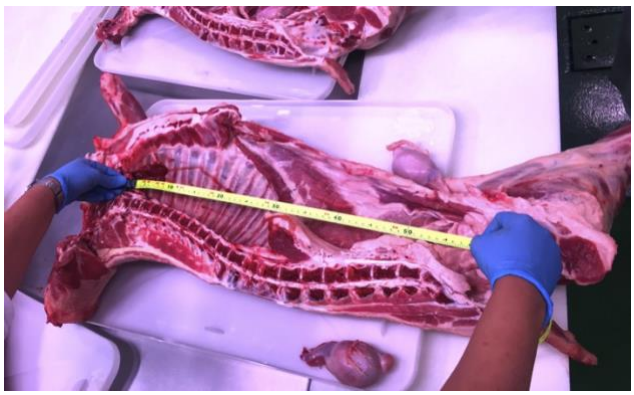
- Centro Tecnolóxico da Carne (CTC)
- Instituto Tecnológico Agrario De Castilla Y León (ITACyL)
- Servicio Regional de Investigación y Desarrollo Agroalimentario (SERIDA)

Centro Tecnolóxico da Carne (CTC)

Centro Tecnolóxico da Carne (Meat Technology Centre) is a public foundation, which is linked to "Consellería de Medio Rural e do Mar" of "Xunta de Galicia" (local authority in North-West Spain). The Centre's aim is to streamline and improve the meat sector competitiveness in Galicia, in all fields of activity and for all breeds. CTC facilities occupy 4,800 m2 on three floors. These include four laboratories for research and analysis (Physics-Chemistry, Chromatography, Microbiology and Molecular Biology), a fully equipped pilot plant, tasting room, three classrooms and assembly hall. CTC's main lines of activity and service are: meat business services (analysis, traceability, HACCP, etc.), R&D&I in the meat sector, consulting and technology transfer, training services (food safety, animal welfare, etc.). One of the most important attributes of the institution is the pilot plant for agricultural research, which has a 50 m2 "dirty laboratory" and a 70.000 m2 field for agricultural testing to transfer new farming and animal breeding techniques to farmers and entrepreneurs. The Centre also has a tasting room, which consists of 10 individual cabins fully equipped according to UNE 87004 and an additional room for sample preparation.

The main research lines for the Centre are:

- Improving meat and carcass productivity and quality in different animal species, breeds and production systems.
- Standardization of product development processes in traditional meat products.
- Emerging technologies for food processing.
- New meat-based products.
- New packaging systems.
- Shelf life studies.
- Food quality and safety.
- Isolation and identification of wild strains for production of starters.



Project team at Centro Tecnolóxico da Carne (Meat Technology Centre) were Jose Manuel Lorenzo, Daniel Franco, Roberto Bermúdez , Laura Cutillas, Martin Miguez, Paulo E.S. Munekata.

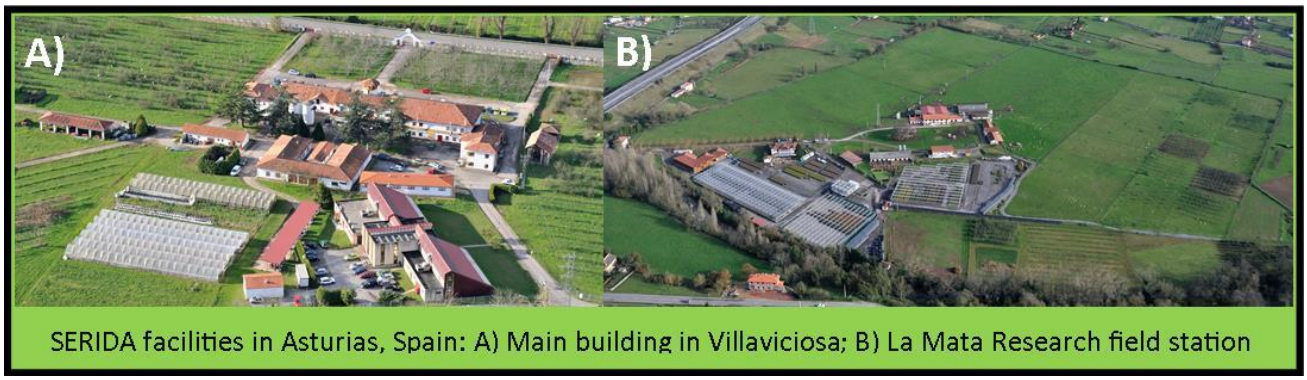
Instituto Tecnológico Agrario De Castilla Y León (Itacyl)

The Technological Agrarian Institute of Castilla y León (ITACyL) was created as a public body under the auspices of the Ministry of Agriculture and Livestock of the Regional Government of Castille and Leon in 2002, confirming more than 100 years of experience dedicated to agricultural research. Institution is the pathway for agri-food sectors in Castilla y León to research in applied agricultural and infrastructural development. The mission of the Institute is to promote the development of innovative agricultural and agri-food capacity of Castilla y León by ensuring that investment in its activities continues to provide benefit to its citizens. The plans of the Institute is to further applied research in agri-business to develop specific technologies and services to satellite centres promoting the agri-food industry of the autonomous community.

This research team has collaborated in several experiments aimed at studying the effects of feeding system on animal performance, such as strategies seeking to reduce methane production within the rumen or improving animal health through the use of plant bioactive compounds. Other studies related animal welfare have involved evaluation of parameters related to the response of animals to induced stress (management systems, transport, environmental stimulants etc) and the use of cutting edge technology application using GPS-GPRS to study the behaviour and improve performance of extensively reared animals. Project team at The Technological Agrarian Institute of Castilla y León (ITACyL) was Raúl Bodas.

Servicio Regional de Investigación y Desarrollo Agroalimentario (SERIDA)

SERIDA is a public body which belongs to the Government of the Principality of Asturias. Most of the territory in Asturias is classified as rural (only 20.5% is considered urban), almost 80% of the land has slopes greater than 20% and more than half is located over 400 m a.s.l. These characteristics impose drastic handicaps to the productive activities while provide a variety of natural resources which have been traditionally used by extensive livestock production systems, including small ruminants. However, these systems have been declining and they are currently facing numerous handicaps which threaten their survival.



SERIDA facilities in Asturias, Spain: A) Main building in Villaviciosa; B) La Mata Research field station

The SERIDA carries out agrarian and agri-food research programs and technological development to address a number of those handicaps. It contributes to the modernization, diversification and improvement of the capabilities of the agri-food sector to increase the productivity and profitability, as well as the conservation of the natural resources.
The SERIDA has got several research centers and research stations in different locations to cover the variety of socioeconomic and environmental scenarios present in the region. The facilities include fully equipped laboratories and experimental farms with its own livestock and trained personnel (from engineers to technicians, operators, etc,).
The SERIDA has notably increased its efforts to transfer the knowledge and experiences to academics, land managers, farmers and other stakeholders by using the latest technologies (@SeridaAst in Facebook and Twitter, its web page http://www.serida.org/, etc.)

The team involved in Ecolamb (Koldo Osoro, Rafael Celaya, Urcesino García, Rocío Rosa García) frequently cooperates with the local breeder associations and maintains close contact with the farmers. The group has long experience in collecting data, conducting research and developing sustainable and innovative strategies for the improvement of the regional animal production systems, including the small ruminants. A number of research projects have explored the potential of sheep in different types of pasturelands and under single or mixed grazing strategies and their role in the conservation of the traditional landscapes.

The Case Study Farm/s and Breed of Sheep for Spain :

The **Castellana** breed is a rustic breed that occupies densely populated areas in the provinces of Zamora, Valladolid, Salamanca, Ávila, Segovia, Soria, Burgos and Palencia. As for the production systems; they are very varied, from extensive to semi-intensive and even mixed systems can be found within the same herd. There are farms with a very traditional management operation with minimal input and others with high technology and precision farming systems in place. We can categorically state that there are no intensive sheep farms, as the Castilian breed is not conducive to prolonged confinement. The size of the herds varies between 150 and 3000 head, which go out each day to graze on their own communal or rented meadows, pastures, stubble or areas where agricultural produce has recently been harvested. Castellana is a multi use breed, however on marginal areas it is mainly utilised for meat production and dairy and wool in cereal areas. Reproductively, it has a continuous cyclicality and matings can be carried out throughout the year, although they usually occur in autumn, with deliveries being concentrated in the months of February and March. The rate of coverings is annual for those on limited diets and in dairy herds, and the well-fed ones can easily provide three deliveries every two years. The breed is known for the very good conformation of the carcasses and a high fat content in milk that makes it suitable for cheese production. Ref. *3 & *4

The production systems for the Castellana breed farms studied have been semi-extensive (Valladolid province) and lamb production in a feedlot (intensive) in the province of Zamora. The farm is located in the centre of the Castilian plateau, with a landscape conformed by vineyards and cereal crops, among holm oak, cork oak and pine forests, and on the river terrace of the Douro river. Young males and newly lambed females are housed. These have a bed of cereal straw and are given forage from vetch, hay and compound feed. The rest of the animals graze every day through pine groves, vineyards and cereal stubble, being supplemented with waste from carrots. Ref *5

The **INRA 401** breed (also known as **Romane**) comes from a selection program carried out by INRA since 1963 in order to improve the prolificacy of the French sheep flock. This breed was created by crossing Romanov (for its prolificacy) and Berrichon du Cher (for its carcass quality) which also facilitated its adaptation to the peninsular climate. It has become a meat breed par excellence, suitable for commercial crossbreeding with other endemic breeds. Its rusticity allows it to be raised in all kinds of regions (plains, mountains, plateaus) and in very varied systems (intensive with permanent housing, extensive with transhumance, etc) (Ref. *6). They are sexually precocious and prolificacy is high, obtaining 2 or 3 offspring per lambing, depending on the period of coverage, feeding, handling and age of the mother. They have easy deliveries since the young are not large at birth. Lambs are responsive and easily reared with a rapid growth rate, thanks to the maternal qualities and lactic aptitude of the ewes. The first intensive farm is in

Zamora, in an area bathed by the river Tera, predominantly dedicated to agriculture and livestock (Ref. *7). Irrigated crops predominate, although it also has an extensive land dedicated to dry land in the high areas near the mountain. It has a climate with long frost periods (from October to the end of April) and low rainfall. Black and white weaned lambs weighing around 15 kg liveweight arrive at the feedlot, where they are housed with a straw bed. They are fed with cereal straw until reaching about 35-40 kg of weight. The other INRA 401 breed farm is located in the province of Salamanca, near a reservoir and in the fertile plain of the river Tormes. The natural environment is characterized by the existence of extensive cultivation fields both rainfed and irrigated and where the predominant activity is agriculture. The farm has 8 buildings where all the animals are kept indoors with access to farmyards (intensive system). The animals have a straw bedding and are fed concentrate feeds, straw and corn silage. The lambs remain tin the farm till they reach 35-40 kg of live weight Ref. *8.

The **Gallega** sheep is a sheep breed of Galician origin that belongs to the branch of producers of the inter fina, whose binomial name is the Ovis aries celtibericus. The breed is presently listed as an endangered native species under Royal Decree 2129/2008, establishing the National Programme for the conservation, improvement and promotion of livestock breeds. Found across Galicia, the breed is experiencing growth in its numbers, in particular on farms in the mountainous areas of Lugo, Ourense, Pontevedra y A Coruña. The breed is mainly and almost exclusively used to produce high-quality meat. The Gallega produces lambs that are small but have meat with special organoleptic qualities, with the breed bred under extensive to semi-extensive conditions. The breed has important characteristics; high fertility and prolificacy, which, together with exceptional maternal nature and high milk yields, means that lambs can survive with virtually no extra support from the farmer. This breed is associated with extensive and semi-free-range breeding regimes: its hardiness enables it to adapt perfectly to its environment, making use of the available resources. The Ovella galega is a sheep of relatively small stature, with a coat that is either all black or white in color. Males develop horns in the form of double-spirals, while in females, horns are generally diminutive if they exist at all. There are two separate ecotypes; Mariñan (‘of the low areas’) and Montaña (‘of the high areas'). The first ecotype generally features heavier sheep, at around 35-40 kilograms in females and 50-70 kilograms in males. The second, native to higher altitudes, tend to be smaller, around 20-35 kilograms for females and 35-45 kilograms for males (Ref *9).

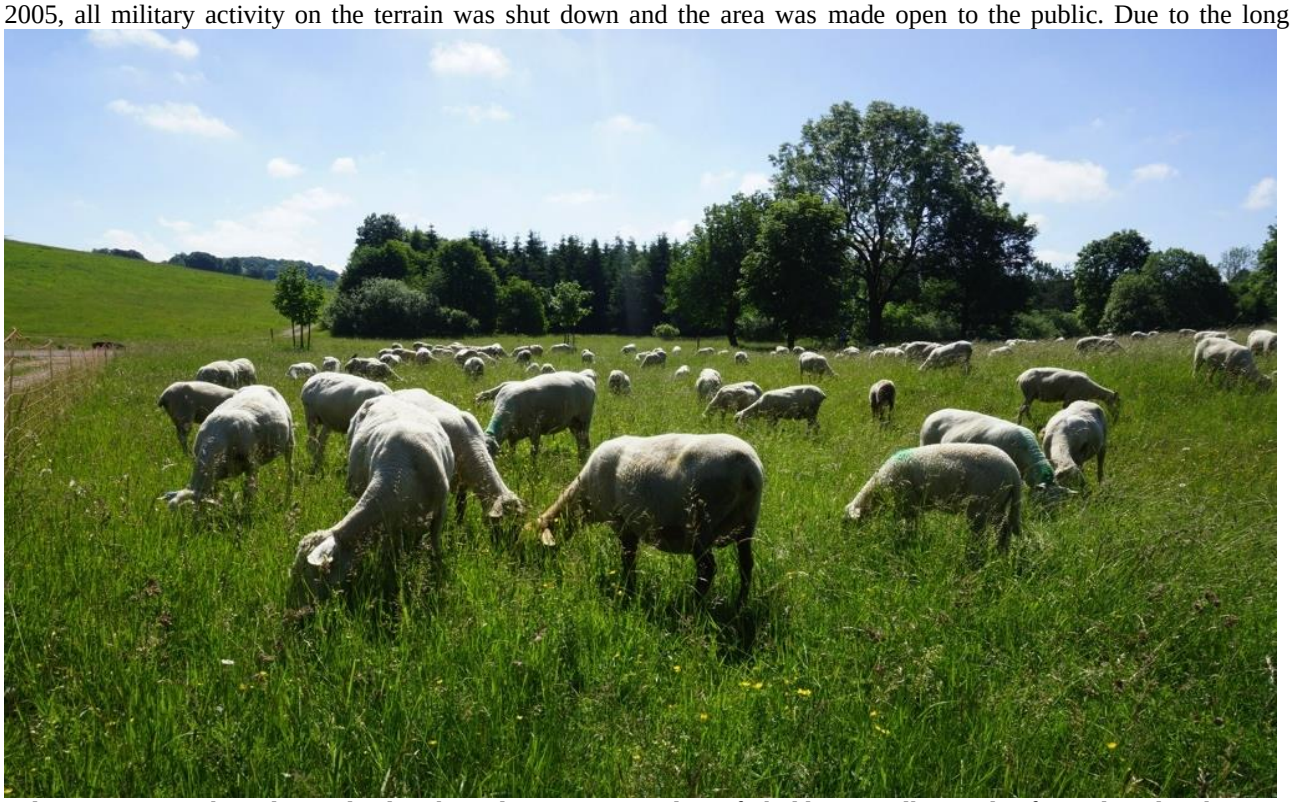
Germany – University of Stuttgart, Department of Life Cycle Engineering

Department building Stuttgart-Vaihingen

Established in 1989, the department's key research area is life cycle engineering and analyses of products, processes and services in terms of their ecological, economic, technical and social aspects, providing a basis for decision-making throughout the entire life cycle. The department Life Cycle Engineering analyses products, processes, and services from an ecological, economic, social, and technological viewpoint extending over the entire life cycle (extraction of raw materials, through production and use, up to end of life) based on the analysis of life cycle-related process chains as well as material and energy flows. The German Project team is lead by Ms.Sc. Andreas Geß and assisted by B.Sc. Anna Tolsdorf. Over the course of the project Dr. Ulrike Bos, Dipl. Ing. Nathanael Ko, Dr. Stefan Albrecht, Ms.Sc. Nathalie Klein and B.Sc. Lisa Fath also supported the project team.

Case Study Farm/s and Breed of Sheep for Germany:

Although the two study areas belong to different bio-regions; **Münsingen to the Kuppenalb, Wildflecken to the Southern Rhön Mountains**, similar conditions can be found due to the similar altitude, climatic medium and an analogous boundary condition with both areas being military training grounds and are located in the same eco-region called the "Western European Broadleaf Forest". Münsingen area was at an abandoned military training area on the Swabian Alb near Münsingen, Baden-Württemberg at 48°26'26.3"N and 9°33'00.3"E at around 775 m a.s.l. altitude. It was used as a training ground for almost a century closed to all civilians, except for shepherds and their flocks. Since 2005, all military activity on the terrain was shut down and the area was made open to the public. Due to the long



military presence, the ordnance load in the soil is immense and it is forbidden to walk outside of paved roads. There are currently around 20,000 sheep grazing the area. The study pasture of 170 ha is leased and managed by an extensive sheep farm nearby. They work with a mid-sized flock of around 500 ewes. The insemination is carried out naturally in spring. During winter, traditional transhumance is practiced to the lower **Swabian areas of Nördlingen**. The sheep graze all year long. Additionally, mineral feed is provided. Around 5 % of the pasture is sheep inducted calcareous neglected grassland, the rest is typical south German grassland. A unique flora and fauna ecosystem has developed due to the century-long exclusion from modern farming or urbanization and constant utilisation by sheep producers.

The second semi-intensive farm near **Wildflecken / Gemünden** is an active military training ground in the Rhön Mountains near Wildflecken, Bavaria at 50°21'0.5"N and 9°50'37.2"E and at around 670 m a.s.l. altitude. It has been used by the army since 1938 and closed to the public, except for rare guided hikes through the area. The study pasture of 330 ha is leased and managed by a semi-extensive sheep farm from Gemünden am Main. They work with a mid-sized flock of around 800 ewes. The insemination is carried out naturally in spring and autumn. During winter a modern form of transhumance is practiced. The shepherd guides the flock to Gemünden, where pregnant ewes can give birth within a stable. In spring the flock travels back to Wildflecken. The sheep graze in summer and are fed hay and concentrated feed in winter. Additionally, mineral feed is provided. As in Münsingen, around 5 % of the pasture is calcareous neglected grassland and the rest south German grassland. Sheep farming is traditionally practiced in the region and has shaped the local ecosystems and species composition.

Both farms use mostly Merino (**Merinolandschaf**), Blackhead (**Schwarzkopfschaf**), **Charollais** and **Texel** sheep. They are interbred to enhance robustness and to make the sheep more resilient against disease. Lambs reach a slaughter weight of about 45 kg on both farmsin about 4-5 months of age. Adult ewes in Münsingen weigh 60 – 80 kg, in Gemünden 90 – 100 kg. The average birth weight of lambs is about 5 kg. Ewes give their first birth at around 18 months of age. Rams are selected carefully to provide genetic diversity and weigh from 90 to 130 kg. The breeds' chest is broad and deep, the back is large with good muscular development and the hips are broad with meaty hind quarters. The fleece is creamy-white. Both farms are focused on meat production and landscape management services.

Portugal – Mountain Research Centre (CIMO)

CIMO is a multidisciplinary research centre in agricultural sciences founded in 2002 within the School of Agriculture (ESA) of the Polytechnic Institute of Braganza (IPB). In 2003, CIMO became part of the national research network funded by the Portuguese Science and Technology Foundation (FCT).
CIMO aims at studying and developing mountain natural resources, forest and agriculture ecosystems, and local food products in order to progress sustainable systems from the economic, social and environmental points of view. Its

diversity allows CIMO to be quite multidisciplinary where researchers have wide experience in developing national and international research projects. The Centre has an established expertise in plant protection, plant nutrition and fertilizer use, ectomycorrhizal symbionts, ecology of plant and animal communities, forestry, land-use patterns, landscape and urban green spaces, mixed farming systems, small-ruminant productions systems, and meat quality and safety.

Case Study Farm/s and Breed of Sheep for Portugal:
The CIMO scientific team has carried out the projects experimental work on two bio-regions; **Mediterranean**, where two farms raise the Churra-Galega-Braganana (**CGB**) breed, located in Braganza, Northeast of Portugal, and **Atlantic** bio-region, where two farms raise the Bordaleira Entre-Douro-e-Minho (**BEDM**) breed, located in Ponte de Lima, in the Northwest region of Portugal.
The farms in the Mediterranean Bio-Region are located in Trás-os-Montes (Northeastern Portugal). The Farm 1 is located at 25 km from Braganza, at an altitude of ~871 m, with a total annual precipitation average of 744 mm and temperature of 11.6 ºC. The highest daily temperatures and the lowest total rainfall frequently occur around June, July, August and September. Braganza climate is warm and temperate, with the rainfall concentrated with the Autumn/Winter seasons. According to the Koppen-Geiger system, the climate is classified as **Csb** (Mediterranean

climate), with an average temperature of 11.6 ºC and average annual rainfall of 744 mm. August is the hottest month with an average temperature of 20.3 ºC, and January is the coldest month with an average temperature of 3.9 ºC. Similarly, August is also the driest month with 14 mm and January is the wettest month with a rainfall average of 100 mm. First farm practices extensive sheep production, where the animals are fed with semi-natural pastures improved by sowing a mixture of perennial ryegrass (*Lolium perenne*) and subterranean clover (*Trifolium subterraneum*). The case study farm flock was around 400 pure breed CGB adult females practicing natural mating.

Farms in the Atlantic bio-region are located in Ponte de Lima, at the Minho region (NW Portugal), at an altitude of ~600m.a.s.l. The climate in Ponte de Lima is warm and temperate; the rainfall occurs more frequently in winter than in summer. The Kppen-Geiger climate classification is **Csb**, and the average annual temperature is 14.8 ºC with a precipitation average of 1228 mm. The driest month is July (16 mm) and December is the month with the highest precipitation (167 mm.) July is the warmest month of the year, with an av. 20.5 ºC. January has the lowest average temperature of the year, being 9.6 ºC. The Case Study Farm flock comprised of ~40 purebred BEDM adult females, submitted to natural reproduction system. The feeding system semi-natural pastures improved by sowing perennial ryegrass (*Lolium perenne*).

Churra-Galega-Bragançana (CGB) sheep breed belongs to the Churro type, which have phylogenetic relationships with the ancestral Ovis aries Studery (DGAV, 1991). These animals are characterized by their large stature, with large legs which give them a peculiar and characteristic aspect, reason why the local producers designate these animals as pernalteiros (long-legged ones). They have a short fleece with an irregular surface and are traditionally used to produce meat as their main function and wool and manure to fertilize the agricultural soils. They are still raised under an extensive production system based on pastoral grazing, in which they are fed with spontaneous pastures that grow in uncultivated, crop residues (cereals stubbles), and improved semi-natural pastures, such as the typical pastures Lameiros. The CGB breed is currently produced throughout the region of Terra Fria (Cold Land) Transmontana, mainly in the countryside of Braganza and Vinhais. The CGB population was circa. 100,000 animals in 1952 (Ref. *10) however, currently, there are 11053 females and 377 males registered in the CGB herd book (Ref *11). The CGB breed presents a great rusticity and stands out due to its ability to adapt to the geographic conditions of mountain areas. The breed's main ability is the meat production, and the productive characteristics of these animals are: birth weight 3.0 to 3.5 kg, weight at 6 months 27.0 to 32.0 kg, weight of adult males 50 to 60 kg, and weight of adult females 35 to 50 kg. The main breeding season occurs in May and June by natural reproduction, and the herds use a male-to-female ratio of 1 ram to approx. 25 ewes. The young ewes, primiparous, are placed in mating between 7 and 12 months of age. The ewes present a continuous reproductive cycle, with a fertility rate of ~90%, prolificacy rate of ~120%. The lambs intended for meat production are slaughtered at 2-3 months of age and are kept with their mothers until slaughtering. The lambs selected as replacement stock are weaned between 3-4 months of age. The ewes show an excellent maternal instinct and can be kept in production until about 8 years of age, usually teeth wear is the main limiting factor to the longevity of the ewes. Males reach reproductive maturity close to 7 months of age, but only initiate reproductive activity around one year of age. The CGB lamb meat is protected by a Protected Denomination of Origin (PDO) certificate designated

by Cordeiro Bragançano. To acquire this label, the lambs must be fed with ewes milk for a minimum of one month of age after which they can be supplemented with local fodder. It is forbidden to use products that might interfere with lambs growth and development such as: hormones, antibiotics, sulfamides, steroids, etc.

The Bordaleira of Entre-Douro-e-Minho (BEDM) sheep breed belongs to the bordaleiros sheep group. There is not much information about the origin of this Portuguese native breed, however they are believed to be descendant from the ancestors Ovis aries Iberian and Ovis aries ligeriensis that populated the Peninsula Galaico-Duriense region. They are small animals and exhibit, predominantly, fleece of crossed wool, however they present a high variance respect to this feature. Some animals present long and good-quality veils, while others have coarse veils of the Churro type. The main mating season takes place in the months of June and July, as these represent the highest abundance of pasture. The ewes start the reproductive activity around 10 months of age, so the first lambing takes place around 15 months of age. The rate of multiple births is low and, traditionally, lambs weaning occurs between the 4th and 5th months of age. Being rustic animals, they are well adapted to the mountain environment and are used mainly for meat production. The meat is essentially used for self-sufficiency by families, however, the local restaurants often seek young lambs as a delicacy at one month of age, but traditionally lambs are slaughtered between 3-4 months of age. Currently, the BEDM population is in sharp decline, partly due to the introduction of improved breeds. The animals of the BEDM breed are raised in small herds, and rarely exceed 15 breeding females. The productive indicators of EBDM are: birth weight of 2.5 to 3.0 kg, weight at 7 months of 15 to 20 kg, weight of adult males 45 to 50 kg and weight of adult females of 30 to 40 kg. The reproductive indicators of BEDM are: fertility of 80 to 90%, fecundity of 90 to 130%, prolificacy of 100 to 150% and productivity of 80 to 120%. The ewes can be kept in production up to 10 years of age and present reproductive activity throughout the year. Weaning of lambs usually occurs between 4 and 5 months of age.

Turkey – Faculty of Agriculture, Adnan Menderes University

Adnan Menderes University, Faculty of Agriculture was established in 1992. The mission of the University is "to educate graduates and researchers who are able to identify national and universal problems and produce solutions and follow the principles of Atatürk with sufficient knowledge, ethical values, awareness of social responsibility and are rational, creative, productive and able to follow world developments; To carry out projects and original research which will contribute to national development and universal knowledge by developing solutions to national and global problems; To provide high quality, reliable and fast service related to societal needs and sensitive to the environment.

As part of the EcoLamb project, personal observations, interviews with farmers and data collection in the field was carried out to determine the ecological footprint indicators and local implicit knowledge in the context of regional sustainable development and livestock production. Based on interviews, there are an average of 300-500 sheep in the herds that took place in the trials. Farmers generally prefer grazing on pastures to improve milk quality in the dairy sheep; however, forage crops are also required to supplement during the cooler months. There is a decrease in pasture productivity due to water scarcity and drought. In regional Turkey, the number of stables per village varies between 50 and 100. One of the main complaints of farmers is support from govt. for pasture improvement. Natural pastures generally contain thyme, mustard, rose grass and daffodils. Grazing period varies from 3 to 6 months depending on the climatic conditions of the bioregion. Interviews and observations carried out in the areas where the study was conducted showed that rural women play a very active role in animal husbandry, especially sheep production and dairy products. Interviews indicated that the income from livestock production is very low and the interest of the young generation in this branch of farming is decreasing day by day. According to the results obtained, holistic production, restorative farming methods and organic farming are recommended. In this context, more efficient use of pastures important for biodiversity, erosion prevention, livestock activities and rural tradition will support the meat production model with low input costs and higher nutritional value. The project team in Turkey was Onur Yilmaz, Ahmet E. Tuzun, Dalya Hazar and Zeynep Burcu Bayrak.

Case Study Farm/s and Breed of Sheep for Turkey:

The project research was carried out in 3 different bioregions in Turkey using 3 varying breeds. The first location in Balikesir is in the transition zone of Continental, Black Sea and Mediterranean climates. The breed used there is Kivircik, regarded as a very important sheep type in terms of meat quality among the indigenous sheep breeds of Turkey. Second farm in Aydın in the Aegean region predominates with a Mediterranean climate, and raised Karya sheep. Little known breed raised only in the western regions of Turkey, is an important sub-type in terms of lamb growth characteristics. And the third farm in Aksaray within the Continental bioregion of Central Anatolia extensively raises Akkaraman the most common and important fat tail sheep breed in Turkey.

In Turkey, livestock production is mostly carried out under extensive conditions and the average age of farmers is over 50 and as such sheep and goat production is carried out almost entirely traditionally using outdated methods. The elderly population dealing with sheep breeding raises concerns about the sustainability of the sector. The results of this project when implemented in Turkey must firstly consider existing consumer expectations. Until that realization the breeders will always consider quantity rather than quality. Results obtained in this project showed that as far as meat quality was concerned, extensive production gave similar results to intensive production. In this regard, extensive management practice will always be preferred to intensive for small ruminants due to cost effectiveness. Absence of a carcass grading system is an important negative factor in Turkey.

SUSTAINABILITY FACTORS

One of the main objectives of the EcoLamb project was to identify, support and promote functional healthier lamb meat from low ecological footprint production systems, conforming to Europe's Sustainable Animal Production mandate. The ecological footprint is a method promoted by the Global Footprint Network to measure human demand on natural capital, i.e. the quantity of nature it takes to support people or an economy. The impacts of the production and consumption of lamb meat are best assessed by accounting for resource use and environmental emissions throughout the full life cycle of a product, and life cycle assessment (LCA) is an important methodology for this. Globally speaking the predominant greenhouse gases emitted from agriculture are methane (CH4) and nitrous oxide (N2O), which respectively possess 28 and 285 times the global warming potential of carbon dioxide (CO2) (Ref.*12). Very few studies to date have attempted to determine the life cycle greenhouse emissions from sheep meat in grazed and intensive lamb fattening systems. Some research has assessed the climate change impacts of sheep production but have not utilized a life cycle assessment approach. With the Ecolamb project we tried to do both with some success and some very important pointers for future research. The trans-national project consortium teams assessed the efficient use of natural resources including water, land, energy, nutrient and genetics within the relevant life cycles, and attempted to differentiate the impacts between the typology of the production systems. The teams used Life Cycle Assessment

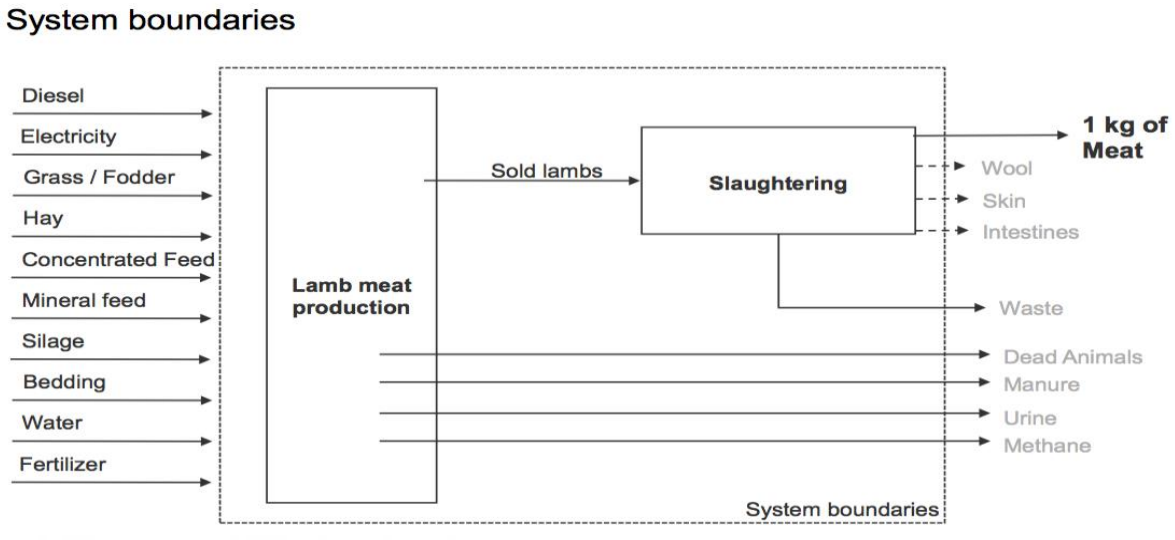
Among the plethora of evaluation methods, life cycle assessment (LCA) across agri-food supply chains is considered to be one of the most informative tools to quantitatively compare environmental performances of multiple farming strategies at the systems level.

(LCA), Life Cycle Costing (LCC), Land Use Assessment (LANCA) and Biodiversity Assessment methods as the universal reference baseline to evaluate the ecological sustainability of Intensive (feedlot) and Extensive (grazing) lamb meat production systems in different bio-regions of Europe.

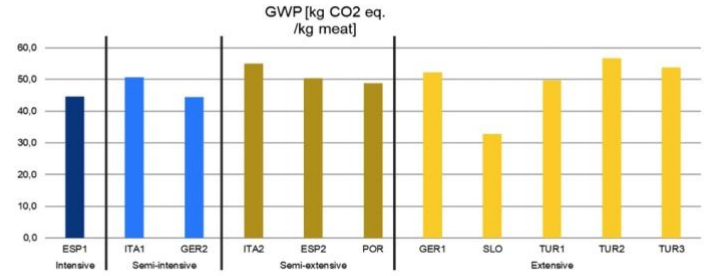
Figure 1 shows the general boundaries of a sheep farm that might be extended to variables that approaches social boundaries (manpower units, relationships with rural areas, tourism and traditional cultural aspects, etc.) and economic boundaries (cost and revenues, taxes and national subventions, local economic advantages of added values, general willingness to pay for environmental goods and ecosystem services).

Life Cycle Assessment (LCA):

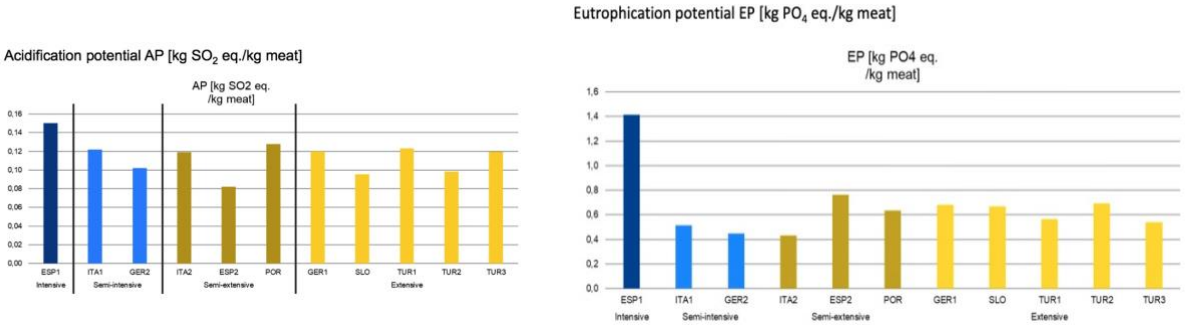
LCA data from all the case study farms used in the project were assessed, and the results can be seen in the following 3 graphs for impact categories Global Warming Potential (GWP), Eutrophication Potential (EP) and Acidification Potential (AP):



Global Warming Potential GWP [kg CO_2 eq./kg meat]



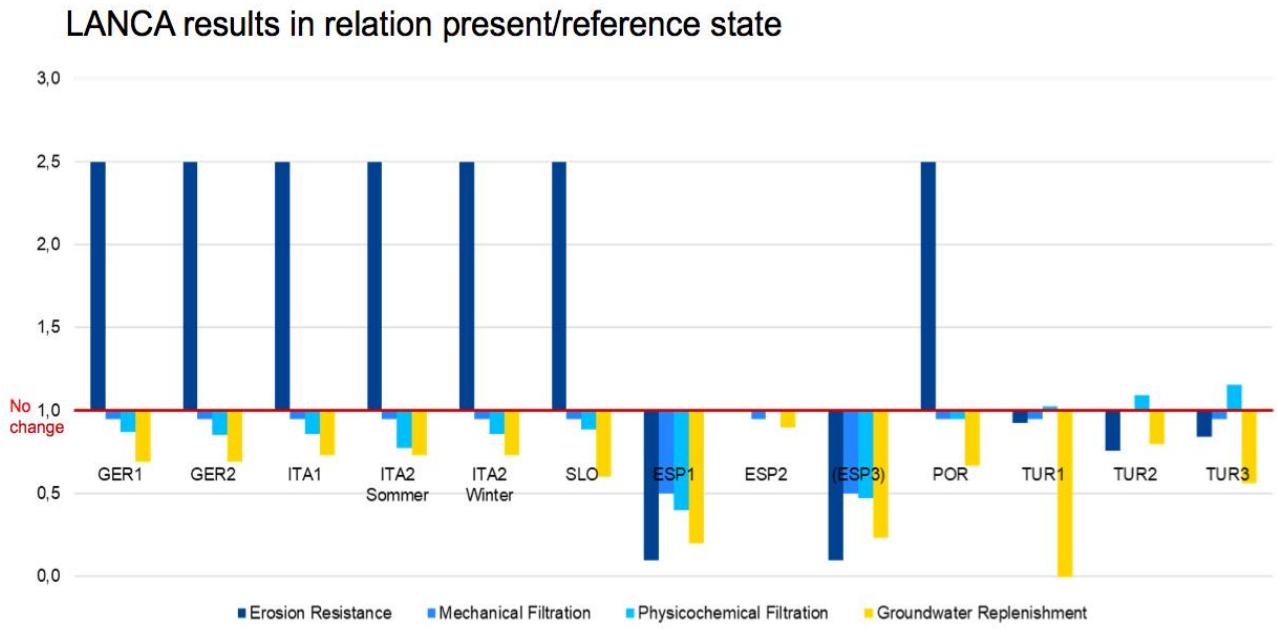
For GWP an average of 49,0 kg CO_2 eq./ kg meat, for AP an average of 0,12 kg SO_2 eq./ kg meat was calculated and for EP an average of 0,64 kg PO_4 eq./ kg meat (Graphs 1, 2 and 3). These numbers are in the upper spectrum of literature data for



LCA results of lamb meat production systems. (Ref *13) For the global parameter GWP, for intensively managed sheep farms bared lower results (e.g. GER2 or ESP1) than the extensively managed ones. For the first local parameter EP the opposite tendency was determined with the most intensive farm (ESP1) showing by far the highest result. The lowest result was found in a semi-extensive farm, while all other case study showed similar results. For the second local parameter, AP, the lowest results within the study were achieved at the rather extensively managed farms (e.g. ESP2 or TUR2). An overall exception is given with the case study from Slovenia (SLO), which showed the lowest LCA results within the study. The reason there was due probably to the high lambing rates per ewe per year. Thereby showing relatively, a lower intake of fodder, bedding, water, etc. and a reduced output of manure, urine, methane, etc. per kg of meat produced. A more precise statement would be to say that if we have less ewes per lambs born, there would be less rumination per kg of meat produced. Therefore, generally speaking, the amount of lambs born per ewe per year is the main determining factor in GWP results. This explains the lower impacts for GWP of intensively managed farms. However, local effects like EP and AP are higher in intensively managed production systems even though they are producing more effectively from a GWP perspective (Ref*14).

Land Use Impact Assessment (LANCA):

The LANCA analysis on 13 case study farms was conducted for the following impact categories; erosion potential (EW), mechanical filtration (MF), physicochemical filtration (PCF) and groundwater replenishment (GWN). The case study ITA2 was split in summer and winter pasture due to the topographic variation of the two sites. In the main, the case studies showed low impacts in comparison to the reference state as can be seen in the following graph;



Graph 4

The values in Graph 4 were calculated by dividing present state through reference state. Meaning that a value of 1 resembles no change, <1 resemble a decrease in the parameter and >1 an increase in the parameter. The exception to the rule is the negative parameter EW. Here, >1 resembles a decrease in the parameter and <1 an increase in the parameter.

Generally, the impacts calculated for the farms were seen as low, except for very intensively managed production

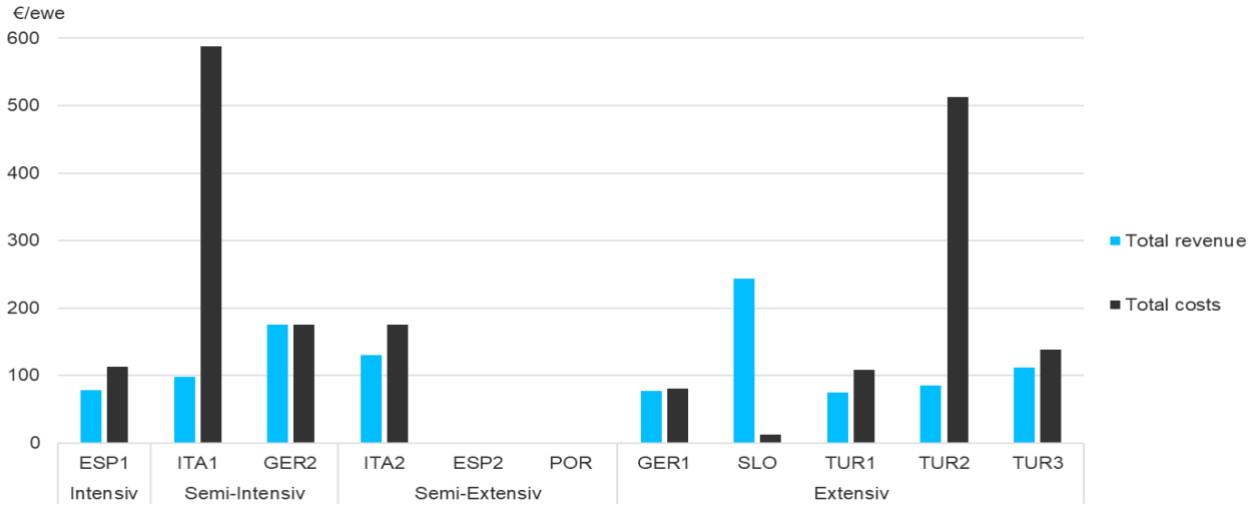
systems (ESP1 and ESP3). The high increase in EW for the intensively managed Spanish farms was due to land sealing for the construction of stables which inhibited erosion. For all extensive case study farms situated in the inland only EW was seen to significantly decrease. The reason being, that the reference state within the respective biomes / forests, which of course hold higher erosion resistance in comparison to pastures. This is emphasized by the Turkish case studies where grassland was set as reference state and no significant change in EW was found.

Life Cycle Costing (LCC) :

The aim of doing a Life Cycle Costing (LCC) assessment for the varying lamb production systems within the EU was to quantify the total cost over the life cycle of an operation to identify the cost-effectiveness between the systems or even with alternative meat production systems for meaningful input into a decision or evaluation process. Sheep farming whilst seemingly an resourceful red meat production operation due to efficient utilization of natural resources may vary in its productivity due to inefficient management processes.

The following graph shows the results for the case studies regarding variable costs, fixed costs and investment costs as well as revenue, earnings and stock value in [€/ewe*a]. Investment Costs include buildings, equipment & rams, earnings are calculated as revenue – costs. Subventions for landscape management services and the stock value of the herd are not included in this assessment.

Grapg 5 - Lamb production costs and revenue:

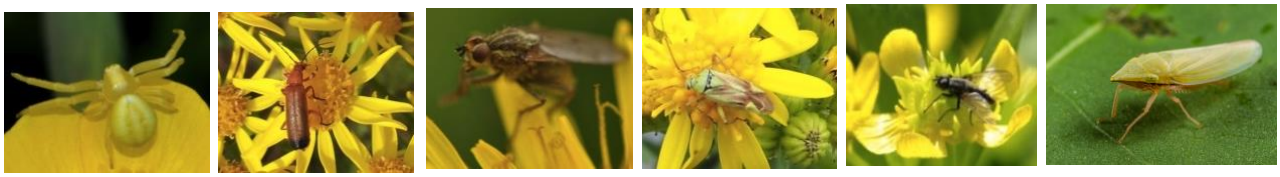


To compare the results shown in the Table above, the median for each production form was calculated. Due to the scarcity of primary data, an LCC analysis was not conductible for all case study farms. From the available data we concluded that the costing ranged from low (extensive 19,76 €/ewe*a) to medium (semi-extensive 25.8 €/ewe*a) to high (semi-intensive 89.42 €/ewe*a). The exceptionally high costs of ITA1 and TUR2 relate to the high wages at those farms. ITA1 for example is a university study farms that is used as a mean of research and not to gain economic revenues. With regards to revenue, the semi-intensive production form showed the highest median return with 136.98 €/ewe*a followed by semi-extensive (109.57 €/ewe*a) and the lowest median of 85.7 €/ewe*a was attributed to extensive production. Generally, only GER2 showed positive earnings without subventions for landscape management services and without accrediting the stock value of the herd.

Our projects outcome related to Life Cycle Assessment has provided landscape-scale assessments on effective use of resources. We feel these outcomes are applicable for strategic and bioregional approaches to sheep farming communities for their improved rural livelihoods. However, there is still a lot of potential for future research on meat production LCA. Inclusion of primary data on rumination and digestion per case study could help to make the LCA results more reliable and precise. The data on rumination and digestion used in our project were literature-based averages. These data could change the end result drastically, especially since the breeds strongly differ in terms of nutrition demand and rumination and hence emission output. The question of reasonable impact categories needs to be further addressed to emphasise GWP in contrast to local parameters or to consider more comprehensively the positive effects of sheep flocks on biodiversity in the assessment of the land use impacts. Partners felt that future research needs to develop a more generally applicable index for animal products which incorporates LCA results, biodiversity impact assessment, meat quality and animal welfare all within the same context so that the assessment data is more readily accessible to the general public.

Biodiversity Assessment:

The local biodiversity inhabiting the different case study farms was characterized using different methods of data recording. In the case of fauna we studied the foliage arthropod community (mostly spiders and insects) as bio-indicators and sampled them with sweep nets as well as visual observations with further detailed assessment in the laboratory.



We also gathered information about the characteristics of the vegetation, especially the sward height, the percentage the main vegetation components (forbs, grasses, shrubs, etc.) as well as the number of flowers and plant species. After gathering all these information we performed different sets of analyses to evaluate if the sheep grazed areas may hold different biodiversity values depending on their degree of intensification, the bioclimatic conditions and/or the type of pastures where animals graze. Finally, we analyzed the fauna-flora relationships to clarify which plant variables were more important for the local fauna communities. A total of 225.271 arthropods (mostly insects and spiders) were recorded during the years 2018 and 2019 in the study farms. They belong to 4 classes, 22 orders and 118 different groups, including 16 families of spiders (O. Araneae), 43 families of beetles (O. Coleoptera), 19 families of true bugs (SubO. Heteroptera), 9 families of leafhoppers, cicadas, ect. (SubO. Homoptera) and 4 families of grassphoppers and katydids (O. Orthoptera). A group of 76.856 arthropods from 46 different taxa belonged to the community of pollinators which include relevant insects such as honey bees, bumble bees, wild bees and hoverflies. These insects are well known by their crucial contribution to the provision of essential ecosystem services like the pollination of plant species which can be important for the animal production systems, but also to maintain more complex ecosystems with high plant diversity. The composition of the community of arthropods differed attending to the degree of intensification, the bioregion where farms were located or the characteristics of the pastures. It may also vary along time in each area depending on multiple environmental factors, like the variability of the climatological conditions or the life cycle of each species. Globally, the sheep systems with lower degree of intensification favored higher biodiversity of the fauna and more complex communities compared to more intensive ones. Sheep grazing affects to the local biodiversity mostly indirectly due to their effect on the vegetation and the environmental conditions in the pasturelands. Fauna communities differed between bioregions, with a gradient of variability from the Alpine (which had the highest abundances) and Continental sites followed by the Atlantic conditions and finally the Mediterranean pasture lands with drastically different fauna. The comparison of the different types of pastures revealed the highest global values in the mountain alpine pastures and the continental grasslands with forests (Fig. 3a) whereas lower abundances and diversity were associated to the pasturelands linked to the supplementation strategies or the improved pastures. The community of pollinators was less diverse and abundant in the improved pastures than in the rest, probably due to the presence of more suitable and heterogeneous conditions in the other pastures for relevant groups such as butterflies, hoverflies or certain families of beetles (Fig. 3b) which require specific microclimatic conditions, availability of resources like shelter, food, humidity, etc.

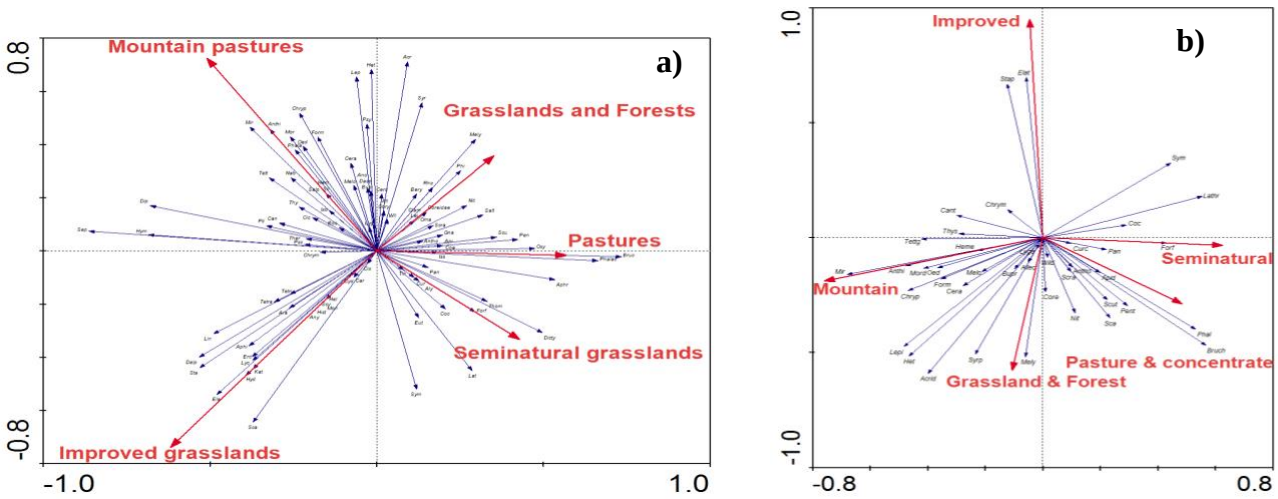
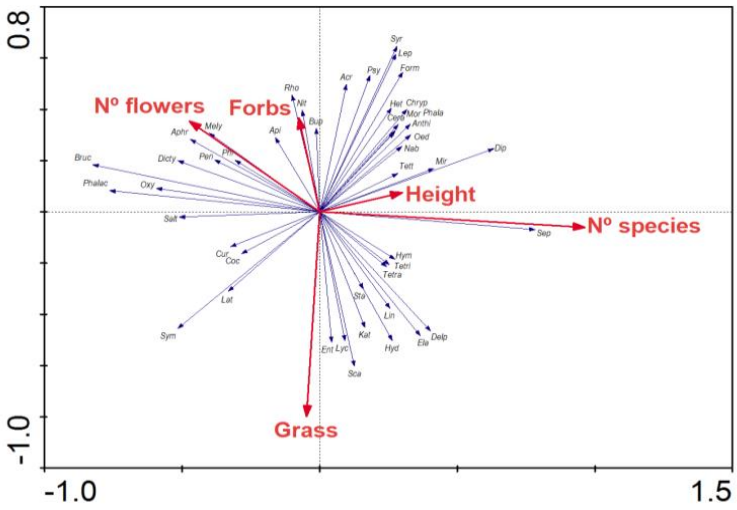


Figure 3. Multivariate analysis (RDA) biplots showing the relationship between the arthropod fauna communities (blue arrows for each arthropod taxa with its name abbreviated) and different types of pastures (red arrows). Pastures refer to sheep farms where sheep graze in the pasture lands but they are also supplemented. The analyses were performed for the whole arthropod community (a) and for the community of pollinators in particular (b).



The differences in the composition of the fauna can be related with the vegetation as it provides a variety of those resources required by the different animal species. Therefore, we explored the plant communities in the different farms and detected subtle differences in the values of plant parameters depending on the degree of intensification whereas several parameters varied drastically between the different types of pastures. Figure 4. Multivariate analysis (RDA) biplots showing the relationship between the arthropod fauna communities (blue arrows for each arthropod taxa with its name abbreviated) and different types of pastures (red arrows for each type of pasture).

The grasses covered higher proportions of the surface in the improved grasslands than in the rest and they had a negative correlation with the surface covered with forbs (herbaceous plants excluding grasses), whose presence in the pasturelands increase the availability of resources (like pollen and/or nectar from the flowers) for the pollinator community.

In summary, these results reveal the complex and varied fauna and flora communities associated to the diverse European sheep systems and valorized the role of the more extensive, mountain and less improved pastures for the conservation of the biodiversity in the sheep grazed areas. The most suitable pastures for the global arthropod community and for the community of pollinators would be those ones associated to sheep management strategies which contribute to maintain heterogeneous swards with balanced vegetation composition which includes grasses, forbs and other plant species which provide varied resources (food, habitat, etc.) for more complex and biologically diverse fauna communities.

MEAT QUALITY

Although sheep meat has a small share (~1.5%) of the total meat production in the EU, sheep farming is of great importance to rural development and the environment. Enhancing the quality of lamb meat of local breeds is essential to ensure both profitability for sheep producers and the conservation of endangered breeds.

Project investigated the impact of sheep production systems on the nutritional content, quality and safety of lamb meat to identify future barriers and make recommendations to industry for improvements. In order to assess these attributes, the partners used the same animals as in the case study farms described earlier. The combination of the 6 nations taking part in the project allowed the analysis of 13 different breeds of lamb various meat quality factors (Table 3).

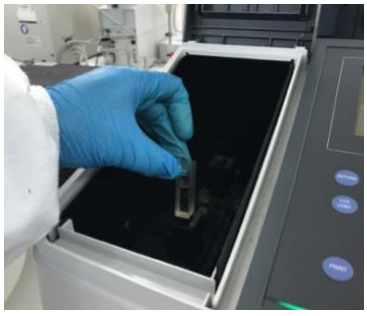
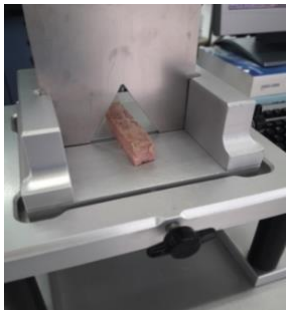
Country	Breed	Breeding System
Germany	Texel-Merino-Swifter-Berrichon (TMSB)	Extensive
	Merino-Charolais-Blackhead (MCB)	Extensive
Spain	Gallega	Extensive
	Inra 401	Intensive
	Castellana	Intensive
Slovenia	Jezersko-Solčava (JSO)	Extensive
Italia	Biellese	Intensive
	Sambucana	Extensive
Portugal	Churra-Galega-Bragançana (CGB)	Intensive
	Bordaleira entre Douro e Minho (BEDM)	Extensive
Turkey	Akkaraman	Extensive + Intensive
	Karya	Extensive + Intensive
	Kıvırcık	Extensive

TABLE 3. BREEDS AND BREEDING SYSTEMS EMPLOYED IN EACH COUNTRY.

The meat quality of the above lamb breeds was evaluated on loin fillets by means of pH and colour parameters. Specifically, three chromatic parameters were analysed; luminosity (L*), red index (a*) and yellow index (b*). The chemical composition, including moisture, intramuscular fat, protein and ash were quantified in lamb loin according to the ISO recommended standards. Fatty acid profile; saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), ω3 and ω6 fatty acids and their relationship (ω6/ω3) were determined employing gas chromatography techniques. Cholesterol value was quantified via HPLC. Finally, the profile of volatile compounds was examined using gas chromatography in lamb loin. The most important compounds were taken into account, and were distributed in 6 different families: alcohols, aldehydes, aliphatic hydrocarbons, aromatic and cyclic hydrocarbons, ketones and "others". As a result of the project we have found that the interaction between breed x production system of the lambs significantly affected all the quality parameters studied. As such, the following analysis differentiation between the countries and their breeds are described;

The **German** breeds (TMSB and MCB) showed intermediate values for all the measures analysed, except for the parameter b* and for the percentage of protein and ash, where they showed the highest value.

For their part, the **Spanish** breeds (Gallega, Inra 401 and Castellana) also showed intermediate amounts for all pH, colour and composition values. However, in the lipid profile, Inra 401 and Castellana breeds were highlighted for containing the lowest percentage of SFA, while Inra 401 obtained the highest values for MUFA. At the same time, Castellana, Inra 401 and Gallega breeds were characterized by having the highest value of aliphatic hydrocarbons, aromatic and cyclic hydrocarbons and ketones, respectively. In addition, Inra 401 breed was distinguished for its low content of aliphatic hydrocarbons.


In the case of the **Slovak** breed (JSO), they had the lowest values for pH. However, values were intermediate for colour parameters and composition percentages, except for protein, where JSO highlighted the lower content. Regarding the lipid profile, JSO breed obtained the highest content of SFA and the lowest content of PUFA, ω6, and cholesterol. Regarding the profile of volatile compounds, the values displayed were intermediate for all families except for aldehydes, which JSO had the highest results.

The **Italian** breeds (Biellese and Sambucana), showed intermediate values for pH, while in the colour parameters both breeds obtained the highest L* value and the lowest a* value. In the composition they were distinguished for obtaining low ash content. The lipid profile was kept in the intermediate range, although the Sambucana breed stood out for containing the lowest ratio ω6/ω3 and the Biellese breed registered the highest concentration of cholesterol. Regarding volatile compounds, the Sambucana breed was distinguished for containing the lowest values of the families of alcohols, aldehydes, aromatic and cyclic hydrocarbons and ketones.

Portuguese breeds (CGB and BEDM), the CGB breed obtained intermediate values for all the parameters except for the profile of volatile compounds, where it stood out for its higher content of alcohols and total volatile compounds. The BEDM breed obtained the highest pH value, while the colour parameters were intermediate. Regarding composition, BEDM displayed the highest percentage of moisture and the lowest fat content. The MUFA quantity was lower for this breed, in total contrast to the PUFA reading, very high ω3 and ω6 percentages. This breed was characterized by having the lowest content of total volatile compounds.

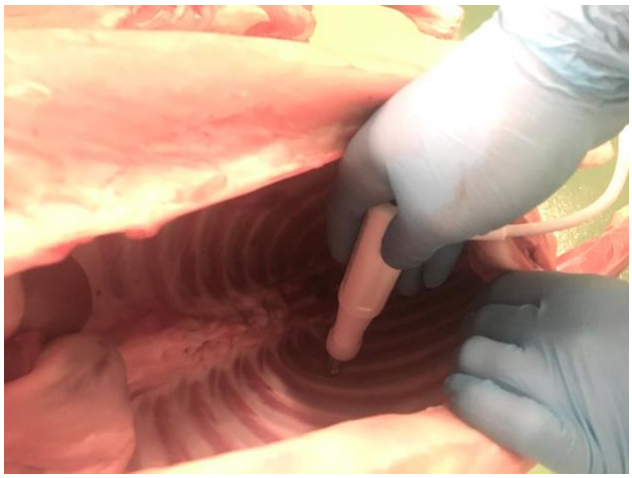
Finally, regarding the **Turkish** breeds (Akkaraman, Karya and Kıvırcık), it should be noted that they generally had the lowest values of L* and b*. At the same time, these three breeds obtained the lowest moisture quantity and the highest fat percentages. Furthermore, the Akkaraman, Karya and Kıvırcık breeds showed the lowest percentages for ω3, while they showed the highest ω6/ω3 ratio.

The present investigation allowed us to conclude that the production system to which the lambs were managed under was greatly affected by the breed studied. Despite these distinctions, several general conclusions have been drawn. We can confirm that intensive production systems provided higher values of L* and the extensive system generated greater proportions of a*, whereas the breeding system did not affect the b* parameter. As well, the extensive systems provided higher fat and protein contents, yet for the lipid profile, the rearing system did not affect the content of SFA. The rest of the parameters, including cholesterol, were all altered in different ways depending on the breed studied. Finally, intensive lamb production farming caused a higher concentration of aromatic hydrocarbons and the extensive system provided higher amounts of alcohols, aliphatic hydrocarbons and total volatile compounds. With respect to volatile compounds, the production system did not affect the content of the aldehydes, ketones and "others" group.

MICROBIOLOGICAL QUALITY OF LAMB MEAT :

Knowledge on exactly how important meat and meat product borne zoonotic diseases are compared with other types of food, drinking water and environmental exposure is quite limited. Occurrences of zoonotic pathogens in raw meat are variable, although most often are between 1% and 10%, depending on the organism, geographical factors, farming and/or meat production practices, etc. The EcoLamb project compared meat pathogen levels from animals raised under varying production systems (intensive, extensive and mixed) in the case study farms mentioned earlier. The evolution of lipid and microbial-induced deterioration in lamb meat was compared between these production systems with the aim of recommending to the sector, packaging to better inform the consumer and promote a healthier lamb meat alternative. This study (i) characterised the evolution of spoilage microorganisms in refrigerated vacuum-packed (VP) lamb meat from a total of 10 farms housing 8 local breeds of Portuguese, Spanish, Italian and Slovenian origin raised in intensive, extensive or semi-extensive regime; and (ii) elucidated how intrinsic properties of meat can affect its microbial spoilage.

Cold carcass weight (CCW), ultimate pH (pH_{24}) and proximate analysis were quantified on carcass/meat from each of the 285 animals raised and slaughtered for this purpose; while mesophiles, lactic acid bacteria, *Pseudomonas* spp. and psychrotrophic bacteria were enumerated during 15-day cold storage. Substantial variability in all attributes were found between the ten farms. CCW of intensively-raised lambs (21.4 kg; 95% CI: 20.6 – 22.1 kg) were higher than the ones in semi-extensive regime (14.9 kg; 95% CI: 14.4 – 15.4 kg), and in turn these were heavier than the extensively raised lambs (12.4 kg; 95% CI: 12.0 – 12.7). Mean contents of protein (76.5 – 87.4% db), fat (3.78 – 13.1% db) and ashes (4.62 – 5.65% db) in lamb meat were highly dependent on the farm type. Although meat from some farms was associated to higher microbial levels, in general, microbial growth was found to be modulated by intrinsic properties of meat. Higher pH_{24}, moisture, protein content and ashes content accelerated spoilage rate; whereas meat from heavier carcasses and of higher fat content presented slower growth of spoilage bacteria. In order to improve the microbial quality of lamb meat, animal handling must be enhanced to minimise pre-slaughter stress; slaughtering practices and hygiene must be improved; and a carcass classification system could be adopted towards the selection of fatter animals and chilled carcasses of optimal pH_{24}.



ANIMAL WELFARE

Growing number of consumer surveys and increase in the demand for animal welfare-friendly food products throughout Europe indicate a high level of consumers' concern for animal welfare. However, stated welfare concern does not always develop into behaviour and two of the reasons for this discordance are the access to welfare information and perceptions of welfare labeling. Trust in the information provided on food product labels, and perceptions of welfare responsibility are the main determinants of consumers' welfare-friendly behaviour. One of the main aims of the EcoLamb Project was to firstly assess the linkage between Animal Welfare and Meat Quality and if specific outcomes were derived to than brand and label the reliable information on lamb meat products based on approved standards. The project partners felt that if solutions could be found at the farm management level, we could incorporate consumer expectations for animal welfare and meat quality to enhance the competitiveness of the lamb meat sector, making it more viable in the future.

Project partners used AWIN Welfare protocol for sheep, which is the only international consensual protocol for welfare assessment in sheep. In each of the case study farms AWIN based management survey was carried out to describe the different procedures used in each of the farm typologies (Extensive, Intensive and Mixed production systems), in the varying bio-regions (Mediterranean, Continental and Alpine) with the designated selection of breeds (13). In addition, specific stress analysis was carried on each lamb by taking frequent wool samples to measure hair cortisol concentrations. This was done to ascertain chronic hypothalamus-pituitary-adrenal axis activity which is an indicator of chronic stress in animals.

Our results showed that all the case study farms analyzed met the AWIN criteria for welfare;

- Good feeding. All the animals had appropriate nutrition and water available in good conditions.
- Good housing. Fleece was mainly clean and only in one particular case animals were subjected to mild heat stress with no access to shade. Ease of movement was ensured always (no need to assess in extensively reared animals), with stocking densities above 1,5 sqm per lamb and no hoof overgrowth.
- Good health. Despite some individuals having small minor injuries, punctuation achieved by all the farms indicated a general absence of lesions in body, head and legs. Likewise, lameness, faecal soiling and ocular discharge were absent, mucosa colour was right (not anaemic), and respiratory and fleece quality presented no issues. Moreover, despite some farms are used to carry out castration, lambs for the EcoLamb project were not castrated.
- Appropriate behaviour. Lambs were kept together (there was no social withdrawal), with no signs of generalized stereotypes or excessive itching. The familiar human approach test revealed an average (and median) flight distance of 2 m, with animals approaching humans after a short period of time (no fear).

Qualitative Behaviour Assessment (QBA) data was subjected to PCA and a plot with the QBA indicators considering data from all the farms was generated (Figure 5). The most desirable QBA scores are for farms described on PC1 positive and PC2 negative values; the least desirable QBA scores are for farms described on PC1 negative and PC2 positive values (Table 4).

	PC1	PC2
Positive	Bright, inquisitive, sociable, content, vigorous, assertive, calm, active, wary, alert, listless, subdued, relaxed, tense, fearful	Agitated, tense, aggressive, frustrated, wary, active, sociable, defensive, bright, inqusitive, fearful, subdued, alert
Negative	Physically uncomfortable, defensive, frustarted, aggressive, agitated, apahtetic	Relaxed, calm, assertive, listless, physically uncomfortable, apathetic

Table 4

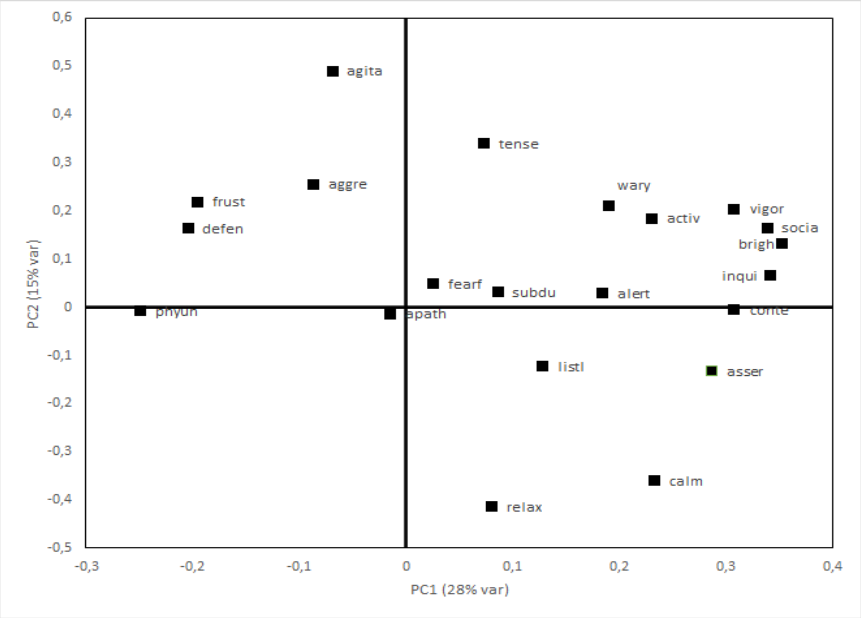


Figure 5. PCA plot with the QBA indicators taking into account the results from all the farms.

Chronic Stress

Cortisol has traditionally been measured in various body fluids and excreta in order to assess stress and pain in animals. However, measured cortisol and its metabolites in these types of samples do not reflect the overall axis response over longer periods of time. The use of hair cortisol as a biomarker is insensitive to the impact of acute stress, such as handling during sampling procedures. Hair is a biomaterial that may accumulate glucocorticoid hormones over weeks to months.

All the partners collected wool samples from each lamb from the same body region (after the first sampling new re-growth hair) on a monthly basis from their birth to the slaughtering date and analysed the cortisol concentrations to assess chronic stress.

In general, lower Hair Cortisol Concentration (HCC) readings were observed with lambs in extensive production systems. Analysis also gave highest readings for lambs during gestation (period in the womb). As well results showed a general adaptation of the lamb to its environment during the 4-month experimental period. Recommendation to industry could be made suggesting that minimizing stress to the ewe during gestation would impact lambs performance. After birth adaptation of the lamb to its

environment over a period of time was seen in all production typologies. The neonatal period is a critical phase of the animal's life cycle but the decreasing activity of the HPA axis evaluated by cortisol suggests the progressive ability of lambs to cope with the environment and a progressive adaptation to independent life. The increased cortisol secretion observed at four months of age could have been stimulated by an increased allostatic load experienced by the growing lambs. An assessment of the resilience and allostatic load of animals could be used to improve their welfare and be evaluated through biological markers, such as cortisol.

Figure 6 shows a typical pattern of cortisol accumulation (two different bioregion and breeding system). High level of cortisol accumulation has been observed in fetal life of lambs and a higher concentration in semi-extensive vs extensive system. These observations are indicative of how the management of the supply chain must take into account its effects on animal welfare and may help to manage healthier livestock production.

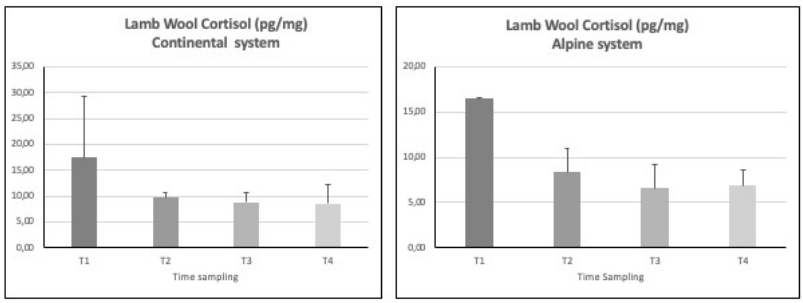


Fig.6 Pattern of mean wool cortisol concentration (pg/mg) in lamb housed in the Continental and Alpine systems during the four-time sampling: T1 = 1st month of life; T2 = 2nd month of life; T3 = 3rd month of life; T4 = 4th month of life

Acute Stress:

The project also attempted to evaluate acute stress albeit only a limited case studies with aim of recommending further research using effective methods. Integration of rumination time and total activity measured by sensors are useful tools to detect stressful conditions in animals. Stressor stimuli can be derived by environmental factors, behavioral discomfort, threat of predators and acute states of pathology. A possible assessment of the number of acute events could make the farmer aware of a potentially dangerous situation for the flock that has an impact on animal management, veterinary care and economical loss. The research identified events that can generate stress in the animals (e.g. extraordinary cleaning of barns, days of weaning, shearing, constant traffic nearby, excessive noise, construction, presense of predatory animals nearby etc.), see Ref*15.

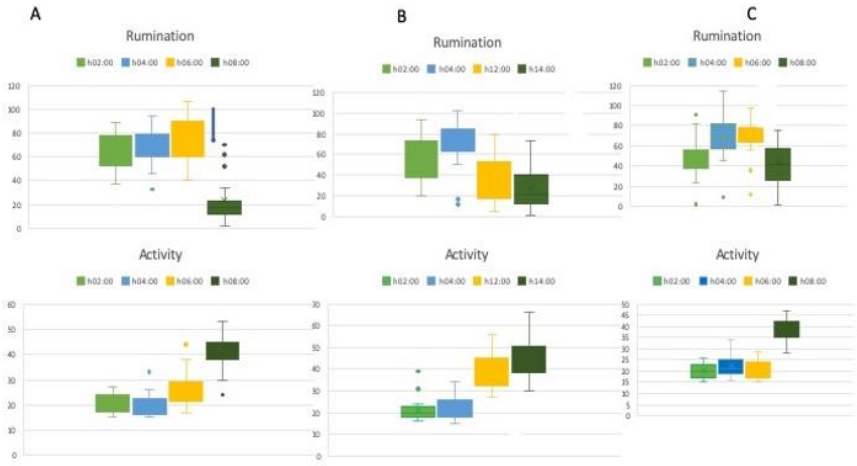
Data were obtained through the assessment of the normality of data distribution through Lilliefors test and when they not have a normal distribution it was evaluated by nonparametric tests. Statistical difference was detected related to not-stressor-stressor transition by Wilcoxon test for paired two-tailed samples. Then, to test a real decrease in rumination or increase in activity by a Wilcoxon test for a single one-tailed sample was carried out on the value of the difference between the values recorded at the beginning of the stressful event and the last value of the not stress phase.

Critical issue

Evaluating stressful events and their impact on animal behavior is not easy because literature has demonstrated an individual variability in response to the stimulus, primarily based on environmental conditions and previous experience of the animals with the same stimulus. However, this example gives the possibility to test the effect since it is known the starting time of the individual stressful events and to compare the variability of each single behavior in relationship with the transition from the state of not-stressed condition to the response to the stressful event.

Positive issue

Sensor analysis was relatively effective for determining changes in rumen and motor activity, statistically sensitive to recognized stressful events.



Data on slaughtering:

Sensors were applied to animals until the last moment of life before slaughter. The effects of acute stress caused by the transport of animals to the slaughterhouse were checked, in particular it has been verified how the sensors can signal the effect of stress caused by transport with or without a rest period before slaughter on some meat quality parameters were analyzed. The animals were divided according to the parameters detected by the sensors into two homogeneous groups; animals highly susceptible to transport stress and animals that were less susceptible. The results show that there is a correlation between the increase in drip loss detected in the meat sample and acute stress. However, this is detected for animals that undergo stress immediately before slaughter, while the animals that can have a rest period do not show significant differences in this parameter. The conclusion of this set of experiments is that the acute stress detected by the sensors can be useful in identifying the subjects most sensitive to transport which results in less quality meat.

FURTHER READING & RELATED PUBLICATIONS

1. Health implication of Biellese lamb meat consumption
A. Brugiapaglia1*, C. Lussiana1, J. Lorenzo2, M. Baratta3 - ICoMST 2019 Italy.

2. Incidence Of Hygiene Indicator Bacteria And Pathogens On Carcasses Of Portuguese Lamb Breeds
Coelho-Fernandes, S.C., Félix-Oliveira, D., Gonzales-Barron, U., Cadavez, V. - AIDA (2019), XVIII Jornadas sobre Producción Animal

3. Physiochemical Characteristics And Texture Of Lamb Meat From Two Authoctonous Portuguese Breeds
Santos-Rodrigues1, G., Lorenzo2, J. M., Gonzales-Barron1, U., y Cadavez1, V. AIDA (2019), XVIII Jornadas sobre Producción Animal

4. Study Of Growth Performance Of Churra-Galega-Bragançana And Bordaleira-De-Entre-Douro-E-Minho Lamb Breeds
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5. Qualitative Behaviour Assessment In Intensively And Extensively Reared Lambs
Bodas, R.; Montañés, M.; Cadavez, V.; Peric, T.; Baratta, M.; Ko, N.; García-García, J.J. - EAAP Conference 2019

6. Microbiological quality of lamb meat raised in intensive and extensive systems in Italy
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7. Evolution Of Spoilage Microorganisms In Vacuum-Packed Meat From Two Portuguese Lamb Breeds
Félix-Oliveira D., Coelho-Fernandes S.C., Gonzales-Barron U., Cadavez V. - AIDA (2019). XVIII Jornadas de Producción Animal

8. Producción Sostenible De Carne De Cordero En Europa Y Evaluación Del Bienestar Animal
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9. Biodiversity Associated To Portuguese Sheep Production Systems
Fernandes, E., Cadavez, V., Celaya, R., Gonzales-Barrón, U., Cerqueira, J.L. y Rosa García, R. - AIDA (2019). XVIII Jornadas de Producción Animal,

10. **Biodiversity associated to European sheep grazed pastures**
Rocío Rosa García1, Tanja Peric2, Vasco Cadavez3, Nathanael Ko4, Joaquim Lima Cerqueira5,6, Ruggero Pietro Stanganello7, Elisa Fernandes3, Rafael Celaya1, Úrsula Gonzales-Barrón3, Mario Baratta7 FAO CIHEAM network, Meknes 2019

11. **Evaluation of physico-chemical parameters of aging lamb meats from "Castilla León"**
ICoMST August 2019 Potsdam, Germany Belén Goméz1, Paulo Eduardo S. Munekata1, Raúl Bodas2, Daniel Franco1, Francisco Allan L. Carvalho3, Mirian Pateiro1, Roberto Bermúdez1, José Manuel Lorenzo1

12. **Evolution of spoilage microorganisms in vacuum-packed lamb meat from two portuguese breeds**
ICoMST August 2019 Potsdam, Germany
Ursula Gonzales-Barron1, Diogo Félix-Oliveira1, Sara C. Coelho-Fernandes1, Gisela Santos-Rodrigues1, Jose M. Lorenzo2, Vasco Cadavez1

13. **Fatty Acid Profile Of Castellana And INRA401 Lambs**
ICoMST August 2019 Potsdam, Germany
Belén Gómez1, Paulo Eduardo S. Munekata1, Raúl Bodas2, Daniel Franco1, Francisco Allan L. Carvalho3, Laura Purriños1, Laura Cutillas1, Roberto Bermú- dez1, José Manuel Lorenzo1

14. **Fatty acid profile of lamb meat from two portuguese autochthonous breeds**
ICoMST August 2019 Potsdam, Germany
Mirian Pateiro1, Ursula Gonzales-Barron2, Noemí Echegaray1, Laura Purriños1, Francisco A.L. Carvalho3, Daniel Franco1, Paulo E.S. Munekata1, Vasco Cadavez2, José Manuel Lorenzo1

15. How to react to the necessity of a sustainable animal production? The EcoLamb project. Peric T., Bergant M., De Marco A., Makorič P., Ogun S.

Sixth International Scientific Conference "JUNE 5th – WORLD ENVIRONMENT DAY", Bihać, Bosnia ed Erzegovina, 18-19 June 2018.

****The reader is invited to check the website www.ecolamb.eu where information on publications of the project are periodically updated**

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