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Livestock grazing systems and sustainable development in the Mediterranean and Tropical areas

Recent knowledge on their strenghts and weaknesses

Alexandre Ickowicz and Charles-Henri Moulin, editors

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Acknowledgements

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This book draws on a body of work conducted by research teams and partners affiliated with UMR Selmet and located on several continents around the world. We would like to express our sincere gratitude to all our research partners (mentioned in the publications cited) and development partners, as well as to the financial partners whose contributions made this work possible. An exhaustive list would be practically impossible to draw up on this page as it would have to include all the research institutions involved (universities, institutes and research centres), the ministries concerned, public and private funding partners, international partner organisations, non-governmental organisations, territorial partners, etc,. Most of these partners are mentioned in the pages of this book or in the bibliographical references cited, but we apologise in advance if this is not the case.

We would especially like to thank all the livestock farmers and their family members who have been active partners in our field research, either individually or as members of associations. This book is primarily intended to be of use to them.

We would also like to thank our supervisory institutions, CIRAD, INRAE and the Institut agro Montpellier, who have always supported us scientifically and provided the means to carry out this work. The latter have enabled the implementation of the UMR Selmet 2015-2020 scientific project, which is the basis for the editing of this work.

Finally, we would like to thank our three scientific reviewers for their time, professionalism and insight, all of which greatly assisted us in completing this book, which is why we invited them to write the preface with full knowledge of the content.

Alexandre Ickowicz and Charles-Henri Moulin

Preface

What if pastoralism could show us the way to an agroecological transition in livestock production, at least in relation to ruminants grazing on grasslands?

This is the question we can legitimately ask ourselves after reading this book, which is dedicated to agricultural and pastoral ruminant farming systems in Mediterranean and Tropical areas. Do these systems not fulfil all the services expected of livestock farming? Are they not in line with the principles of agroecology, where diversity is an asset and ecological processes should be promoted as a substitute for synthetic inputs, and where adaptive processes are the key to increasing sustainability? Are they not the pillars of sustainable territorial development in the South?

This book proves that livestock on pasture is adaptive, innovative, efficient and effective. This book convincingly disqualifies images of a static sector, locked into multi-millennial traditions and constrained by hostile environments, and defeats the most pessimistic scenarios in a changing and uncertain world.

The studies compiled in this book describe the most recent work conducted by the Selmet joint research unit on the status, function and externalities of livestock systems in the South, analysed in the light of the Sustainable Development Goals established by the United Nations member states and taking into account the diverse, complex and dynamic contextual contingencies of the Mediterranean and Tropical areas.

Certainly, it appears from the various chapters that there is no single form of Mediterranean and Tropical grassland farming systems and that, as with all forms of agriculture around the world, several models coexist and interact within sometimes restricted territories. This coexistence of models, which is necessary for the sustainable development of the territories involved, is not the subject of this book; however, we believe that the cases presented are examples and approaches that research and development stakeholders should study in their approach to designing the livestock production systems of the future, as they are expected to be at the end of the agroecological transition.

These approaches relate to biological processes and the intrinsic properties of the entities that make up the systems (plant and animal), but also to organisational processes, including the management of the systems (breeding practices), and finally to the socio-technical environment in which the livestock farmers evolve (family circle, upstream and downstream stakeholders in the sectors, public policy stakeholders).

Two aspects are of particular interest to us, insofar as the research approaches that apply to them are not necessarily obvious at first glance and for which the various chapters provide substantial insights. These include, on the one hand, the role and status

of local practices and resources, which are deemed to be adapted to the constraints of the environment and the expectations of the societies in which they have evolved, and, on the other hand, the role and status of innovation processes, in particular technological ones.

In relation to the first aspect, for the various examples drawn from African, Asian and South American lands, the question is raised as to which elements and forms of production (animal and plant) are most likely to confer the expected multi-performance to the systems (food production, income, savings, labour, soil protection, environmental conservation, etc.). The recent development of livestock farming in these regions has largely been based on the transfer of genetic material, practices and technologies from northern countries and the associated value chains. Can the necessary agroecological transition usefully combine both, as is the case, for example, with farmers who use cross-breeding or those (often the same ones) who rely on multispecies cover to ensure the fodder production necessary for feeding the herd? Moreover, how can better use be made of a plant resource whose condition and management methods show increasing pressure? How can it respond to a rapidly changing demand in terms of production volumes and methods? In all these cases, adaptation procedures as we have known them must undoubtedly evolve considerably, for example by incorporating the capacity to coexist and to provide the system with mutually complementary properties. In our opinion, multi-criteria evaluation approaches will play an increasing role at all levels of organisation (from the individual, a component of the system, to the territories in which different systems cohabit).

For the second aspect, the question is how the agroecological transition and technological innovation can be reconciled and reinforced. This partly involves the first point, with technologies related to resource management and genetic selection, but also involves digital technologies at the service of the agroecological transition. The issue appears quite clear: it is a question of implementing the means to acquire data on the system status (from the resource to the consumer) in order to manage it (adjust practices), in particular as regards the above-mentioned ecological processes. It is largely due to the complexity of accessing this system status that systems have become more streamlined, more specialised and increasingly dependent on inputs and value chains, which are easy to quantify and qualify. As the authors illustrate in this book, digital technologies, provided that they are accessible and replace other expenditure items (and therefore allow for efficiency gains), will be valuable levers for the agroecological transition of grassland systems, and even more so for agro-pastoral systems, for which knowledge of the system status (animals and above all plants) is particularly difficult to acquire.

The diversity of the situations investigated and the clarity of the analytical framework provide valuable information on what the future of grassland and agro-pastoral livestock farming in the Mediterranean and Tropical regions could be, not only in these areas but also in all regions of the world, for all these systems. They make it possible to raise the

debate on the contributions and societal acceptability of an agricultural activity that is the subject of much criticism. The body of work presented here will undoubtedly constitute a reference for those involved in research, development, education and training, all contributing to defining the livestock systems of tomorrow.

Pierre Gerber, Senior Livestock Specialist at the World Bank
Stéphane Ingrand, deputy head of Department PHASE at INRAE
Sylvain Perret, Head of Department «Environments & Societies» at CIRAD

Preamble

This book was inspired by the work carried out by our «Mediterranean and Tropical Livestock Systems» joint research unit (UMR Selmet). Created in 2011 in Montpellier, it was then composed of approximately sixty permanent staff from CIRAD and INRAE research institutions and research professors from the Institut agro Montpellier.

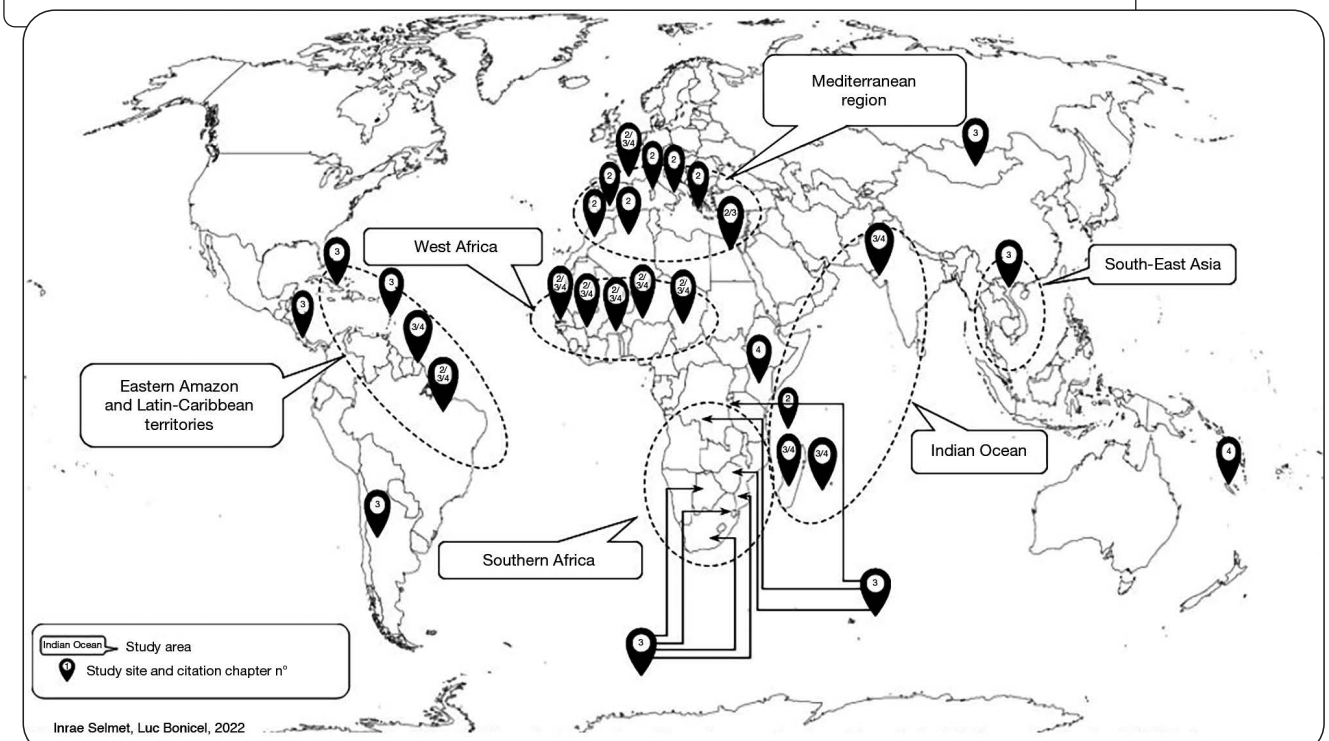
The history of the organisation of French livestock research has made UMR Selmet a quite specific unit in the French landscape. Due to the mandates given to us by the unit supervisors (CIRAD mandate for pastoral and agropastoral systems in the developing countries of the South, INRAE and Institut Agro mandate for agropastoral livestock systems in the Mediterranean area), we have focused the unit's 2015-2020 scientific project ***on family-run ruminant grazing systems in the Mediterranean and Tropical areas***. A major characteristic of these farms is the use of spontaneous vegetation (pastures, meadows) or crop residues for grazing, within rather extensive systems that do not, by definition, use permanent labour outside of the family. The unit's project consisted in analysing the roles of these family-run ruminant grazing systems in meeting the challenges of food security, environmental preservation and societal demands (economy, environment, social cohesion), simultaneously or in interaction with other livestock development models. This key project had three objectives: (i) to strengthen the adaptive capacities of these farms, (ii) to improve their social, economic and environmental efficiency, and (iii) to promote innovation processes so that these farms can take their place in the agroecological transition.

Globally, these family ruminant grazing systems have generally been less studied than other systems, as research efforts have tended to support the dynamics of livestock intensification and industrialisation. However, due to their capacity to mobilise a diversity of resources from very little-managed ecosystems and to recycle agroecosystem biomass, these livestock systems have a number of advantages in the context of the questions raised by the agroecological transition of agriculture and livestock farming in particular. Through this book, we wish to provide a synthesis for the various stakeholders in the livestock sector based on the numerous multi- and interdisciplinary studies carried out by our group over the past ten years and published in scientific journals (see map 1 indicating the sites studied). This book does not claim to be exhaustive in terms of themes and results on these livestock systems, but aims to propose, on the basis of current understanding and our work, clear messages on their potential contribution to sustainable development in the territories concerned. In our view, these livestock systems suffer from a lack of interest and investment by both scientists and development institutions, and we

wish to demonstrate the specific, even unique, assets they possess to contribute to the development of sustainable food systems.

We must also point out that although this collective work was written exclusively by researchers from our UMR Selmet, with a few exceptions, the vast majority of the work was carried out on site in collaboration with researchers from partner countries in the North and South, present in the citations and references presented in the bibliography.

Map 1. Research sites mentioned in the book and geographical areas of privileged partnership.



1. Family-run ruminant grazing systems in Mediterranean and Tropical areas and the challenges of sustainable development

Alexandre Ickowicz, Charles-Henri Moulin

For several decades, the contribution of livestock farming to sustainable development, in its economic, social and environmental components, has been called into question due to its negative impacts on:

- the environment (pollution, climate change, desertification, deforestation),
- animal welfare,
- biodiversity management,
- human health,
- and food security.

But livestock production is also highlighted for its contribution:

- to the reduction of poverty and hunger,
- to the efficient functioning of agrarian systems that incorporate crops and livestock,
- and to the development of local resources.

There is great diversity in livestock production around the world. This diversity is defined by species, livestock systems, agroecological contexts and levels of intensification (Steinfeld *et al.*, 2006; Robinson *et al.*, 2011). It can be observed at global, national and sub-national scales. Speaking of the contribution of livestock farming to sustainable development, in particular in agriculture and territories, is therefore hardly meaningful in general terms. In fact, this contribution must be broken down by type of livestock system and then analysed according to the biophysical and socio-economic contexts that can considerably modify its profile and impacts.

The purpose of this introductory chapter is to explain why family-run ruminant grazing systems in the Mediterranean and Tropical areas have been targeted in this book and through available statistics, to assess the significance of these livestock systems worldwide. Based on the 17 Sustainable Development Goals (SDGs) as defined in 2015 by

the Member States of the United Nations (UN), we can then analyse how these livestock systems can be means, constraints or targets for sustainable development. This approach will allow us to illustrate the general framework of analysis that we have used over the past decade to organise research. This research is presented here under three research themes: adaptation, efficiency and innovation of family ruminant grazing systems in Mediterranean and Tropical areas.

Ruminant grazing systems in Mediterranean and Tropical areas

Globally, ruminants (cattle, buffalo, small ruminants) account for 96% of domestic herbivores. Equids and camelids make up a small proportion of the total, but can be regionally significant in Mediterranean and Tropical areas (dromedaries in arid zones in Africa and the Middle East, Andean camelids in South America, horses and donkeys used for animal traction in sub-Saharan Africa, etc.).

Ruminant livestock systems...

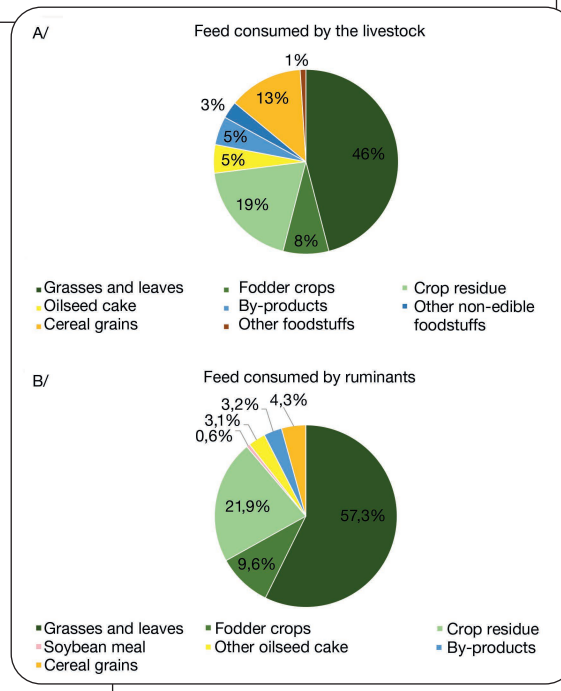
Ruminant livestock are important suppliers of foodstuffs. They contribute almost exclusively to the 883 million tonnes of milk produced (FAOSTAT, 2019), including 81% from cattle and 15% from buffalo. However, cattle and buffalo provide only 22% of the 337 million tonnes of meat, with poultry (39%) and pork (33%) being the largest contributors.

To ensure these productions, livestock consume 6 billion tonnes of dry matter (DM) from various feed resources annually (Figure 1.1). Fodder resources, mainly used by ruminants, account for three quarters of these resources, the remaining quarter being concentrated feed, of which one third is consumed by ruminants and two thirds by monogastric animals (Mottet *et al.*, 2017 and 2018). Some of these resources are consumed by humans (cereal grains, soybeans, etc.), whereas others are not (grasses and tree leaves taken from uncultivated areas or crop residue). The production of these resources occupies 2.5 billion hectares, most of which (almost 2 billion hectares) is "permanent grassland", a term that covers a variety of vegetation types (grasslands, savannahs, steppes, etc.). Of these grassland areas, only 685 million hectares are estimated to be arable (Mottet *et al.*, 2017). On a global scale, herbivores therefore use spontaneous vegetation of just under 1.5 billion hectares that cannot be cultivated. The rest of the food resources come from cultivated areas (0.53 billion hectares). For example, one third of the area cultivated with cereals is used for animal feed.

The value of ruminant livestock is therefore linked to the issue of competition for agricultural land between the production of food for humans and feed for animals.

Monogastric animals are more efficient than ruminants in terms of feed conversion, this is put forward as a reason for preferring the former as a means of preserving natural ecosystems by limiting their use by domestic herbivores. The consumption of

Figure 1.1. A. global composition of feed consumption by livestock (6 billion tDM/year). B. global composition of feed consumption by ruminants in particular (4.99 billion tDM/year). According to Mottet *et al.*, 2017 and 2018.



Forage crops: cereal and legume silage, fodder beet.
Crop residue: straw and cane, stalks, white tips of sugarcane.
By-products: bran, corn gluten, molasses, pulp, grain-energy residue.
Other non-edibles: decommissioned cereal, fishmeal, swill, synthetic amino acids, lime.
Other edibles: cassava pellets, legume and soybean seeds, rapeseed and soybean oil.

1 kg of plant protein allows monogastric animals to produce 0.54 kg of animal protein for broilers and 0.40 kg for pigs, compared with only 0.08 to 0.24 kg for milk or meat production in ruminants, for different French breeding systems (Laisse *et al.*, 2019). However, monogastric animals use a significant percentage (from 26 to 40% depending on the system) of protein from feed that can be consumed by humans. The calculation of a conversion rate of non-edible protein to produced protein can then clearly be seen to the advantage of certain ruminant farming systems: 0.88 kg of produced proteins per kilogram of non-edible protein for broilers compared to 1.28 or 2.17 kg for

the most efficient ruminant systems, i.e. the greatest users of fodder, thanks to microbial fermentations in the digestive compartments (Laisse *et al.*, 2019). These results are consistent with those of Mottet *et al.* (2017) who are investigating the conversion of human edible protein. Using data from the United Nations Food and Agriculture Organisation (FAO), these authors demonstrate that, globally, ruminants consume 133 kg of dry matter of feed to produce 1 kg of protein, compared to only 30 kg of dry matter for monogastrics. However, the conversion rate to protein edible by humans is much better for ruminants: 1.67 kg of protein produced for the use of 1 kg of protein edible by humans thanks to digestive fermentation, i.e. a multiplying effect, compared with only 0.5 kg for monogastrics, i.e. a reducing effect.

Ruminant grazing systems...

Due to their use of feed that are not edible by humans and produced on land that is largely unfit for cultivation, we are particularly interested in ruminant livestock that consume coarse fodder taken directly from the pasture.

In terms of feeding practices, the FAO (Sere and Steinfeld, 1996; Campbell *et al.*, 1999; Robinson *et al.*, 2011) distinguishes and maps global livestock production into three main types:

- *landless or feedlot systems*, where animals are kept in buildings or pens, with feed provided, and where less than 10% of the feed resources come from the farm;
- *grazing systems*, where more than 90% of the livestock feed resources come from grazing land, grassland or cultivated fodder;
- *crop-livestock mixed systems*, where both types of activities are integrated on the farm with more than 10% of the farm income coming from non-livestock activities and where more than 10% of the animal feed resources come from crop by-products.

Only 3.7% of the cattle population are raised in feedlots providing 5% of the protein supplied by cattle (Table 1.1). The vast majority of ruminants are raised in grazing and mixed systems.

Grazing systems span two broad and distinct situations, as outlined in the High Level Panel of Experts on Food Security and Nutrition (HLPE Report 2016).

The first type is Pastoralism. Pastoral systems are distinguished by herd and people mobility, the use of jointly managed resources and animals that can use the vegetation on grazing lands. These systems represent one of the few opportunities for agricultural activities in arid areas where rainfall, water resources and biomass production on grazing lands are low and irregular. Pastoralism is predominantly practiced in the developing world, and supports more than 500 million people (IYRP, 2021). It is still present in the Mediterranean basin, both on the northern and southern shores, even though it is tending to decline. In mainland France, for example, Pastoralism involves 35,000 farms "with substantial livestock" whose forage system is considered to be grazing, i.e. 18%

Table 1.1. Contributions of different ruminant systems to total annual global edible protein production (Mottet *et al.*, 2018).

Species	Production systems	Population (millions)	Production (t of protein)	Share of protein production by species (%)	Share of global protein consumption (%)
Cattle	Grazing	508.8	10,338,175	35	5.1
	Mixed	906.4	17,306,165	59	8.5
	Landless	55.3	1,518,764	5	0.7
Buffalo	Grazing	36.4	584,321	15	0.3
	Mixed	160.7	3,403,574	85	1.7
Small ruminants	Grazing	925.7	1,224,623	43	0.6
	Mixed	1,167.1	1,656,386	57	0.8

of all farms. This system is particularly represented in the Mediterranean and mountain regions, which have close to 1.5 million livestock units (Agreste 2010 agricultural census - Idele processing).

The second form of pasture-based livestock production is grass-based, practiced on grasslands that are generally fenced, whether in the grassland areas of developed or developing countries, or in forested areas after clearing and planting long-term grasslands (e.g., Amazonian forest). Highly productive animal breeds are generally raised there. In addition to permanent grasslands, forages sown with improved species are also used, with a more or less high reliance on inputs. The mechanization of forage harvesting and distribution can lead to a decrease in the proportion of resources taken from direct grazing in the diet. The intensification of these grass-based systems and their ecological impact can vary considerably across the different biomes (HPLE, 2016; Chang *et al.*, 2021).

In addition, mixed crop-livestock systems cover a wide range of situations. They are numerous in developing countries, in particular Africa and Asia, where they are managed by smallholders. The families raise a few animals, often combining several species: poultry and pigs, but also ruminants (notably used for draught). These species contribute to the maintenance of the fertility of the cultivated soils. These smallholder farms produce around 80% of the food consumed by humans in Asia and sub-Saharan Africa (HPLE, 2016). Ruminants are fed from crop residue and fodder crops (grazed or delivered green or after storage), grasses from crop weeding or from foraging on roadsides and plots. They may also have access to grazing areas. As a result, depending on the context (number of animals on the farm, population density and land use in the area),

ruminants can be kept in permanent stalls or grazed on crop residue left in the field and on areas of spontaneous vegetation. These mixed systems are also encountered in developed countries, with greater dimensions (surface area, herd size), although they have tended to decrease with the general decrease in the number of farms. These facts are associated with the expansion and specialisation of farms and areas, in the movement to modernize agriculture since the end of the Second World War, for example in Europe.

Ruminant grazing systems in family-run farms...

In this book, we will focus on family-run farms, which are largely prevalent on a global scale (Bosc and Sourisseau, 2019; Cirad, 2013). Family farms are defined as "the organisation of agricultural production characterised by organic links between the family and the production unit and by the mobilisation of family employees, excluding permanent wage labour. These links are reflected by the inclusion of the operating capital in the family assets and the combination of domestic and operating logics, both market and non-market, in the processes of allocating family labour and its compensation, as well as in the choices of product distribution between final consumption, intermediate consumption, investment and accumulation" (Cirad, 2013). This family-based agriculture coexists with two other major forms of agriculture:

- business agriculture, which uses exclusively paid employees and whose farm capital is held by stakeholders disconnected from family values,
- entrepreneurial agriculture relying on permanent employees to supplement family labour, but whose farm capital is family-owned.

As the types of farms are not identified in agricultural statistics on a global scale, it is difficult to assess the contribution of family-run farms to the global food system. Nevertheless, some elements can be highlighted. They represent the vast majority of the world's agricultural systems, with around 570 million farms and 1.3 billion agricultural workers, for a total agricultural population estimated at 2.6 billion people (Bosc and Sourisseau, 2019; Cirad, 2013). Family-run farms play a major role in the income and livelihood of the population in many countries around the world. However, it is important to consider the extent of the poverty that affects these farming households. With few resources and often very limited land areas (85% of farms worldwide have less than 2 ha; Robinson *et al.*, 2011), these households first try to meet their own food needs. Their farming activities also contribute to income through the sale of the surplus, in particular animal products. Even if they are considered by some to be of low productivity and inefficient in meeting the challenges of global food security, family farms nevertheless provide the bulk of the world's basic food production of plant origin (cereals, tubers, plantains). As regards other crop production, the contribution of family-run farms is more variable: from 40% for palm oil to more than 90% for coffee, cocoa and cotton. The authors of the CIRAD report (2013) did not attempt to estimate the contribution of family farms to the production of animal products. The field studies we conducted suggest that family farms make a significant contribution to

the supply of animal products. For example, in India, the world's largest milk producer, milk is supplied by a large number of small herds. Livestock in family-based farms also provide services for crop production (manure, draught power) and thereby also contributes to food security.

Family farms, as well as the livestock activities that are developed within mixed crop-livestock systems or grazing systems, are very diverse, depending on access to resources and bioclimatic conditions. This determines the potential for change in family units and their activities. There is a controversy over whether family farming can effectively contribute to food security while ensuring environmental sustainability. This is certainly an issue, and in this book we will see that livestock activities, in particular ruminants, can be a lever to contribute to this.

Family-run ruminant grazing systems in the Mediterranean and Tropical areas

This book focuses on family-based grazing systems in the Mediterranean and Tropical areas where our work has been targeted.

These Mediterranean and Tropical regions account for a very large share of the world's domestic herbivore population (Table 1.2.): the vast majority of buffalo, camelids and goats, species that are particularly well adapted to arid or mountainous areas; and around 60-80% for cattle, equines and sheep. Similarly, livestock production in these areas accounts for the majority of the global milk and meat production (Tables 1.3 and 1.4). For camelids and buffaloes, almost all milk and meat production is of course from these areas, as these species are not present elsewhere in the world (or only anecdotally). The Mediterranean area is the main contributor for certain products, notably sheep's milk, representing 50% of global production. For cattle, with 22% of the total population, the

Table 1.2. Herbivore populations, in millions of heads, in the Mediterranean and Tropical areas (FAOSTAT, 2019).

	Cattle	Buffalo	Sheep	Goats	Camelids	Equidae
Mediterranean Basin	96	4	194	72	6	13
Sub-Saharan Africa	319	0	297	409	27	27
South and South East Asia	340	178	179	360	1.6	10
South America[1]	421	2	77	37	9	34
Global population	1,511	204	1,239	1,094	47	118
Med. and trop. (%)[2]	78	90	60	80	84	71

1. Central America, the Caribbean and South America.
2. Percentage of the world's livestock population in the Mediterranean and Tropical areas.