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THE FUTURES OF LIVESTOCK FARMING
IN AGRI-FOOD SYSTEMS

Foresight analysis and multicriteria assessment of scenarios

Aurélie Wilfart and Jonathan Vayssières, eds

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Table of contents

Preface

"What do we want to eat?" This is a very important question that may, in the future, very well become "what can we eat?". Our biggest challenge today is to somehow find a way to reconcile these two questions, keeping in mind that the verb "can" in this sense refers to various issues such as climate, biodiversity, soil, water, the atmosphere and purchasing power, as well as health issues and even world peace.

The livestock sector often leaves a large carbon footprint and as such, it is a key component in the choices to be made in future food systems. Most (but not all) of the scientific community admits that livestock farming is a major lever for successfully bringing about out the necessary changes that we will need to make. In general, there are no scenarios or foresight analyses that allow us to consider sustainable agriculture (closed nutrient cycles) without including livestock farming. Therefore, the main aim of this book is to remind readers how important this sector is by using synoptic and recent data illustrated by various well-documented case studies.

The livestock sector is a major source of income, food security and social stability for millions of farmers and livestock holders around the world. Livestock farms help maintain soil fertility via the production of organic fertilizer, which will be used to gradually replace mineral (synthetic) fertilizers. These farms can also draw on draught animal power to work the fields and for transportation purposes, which can then in turn increase agricultural productivity in systems that combine livestock farming with crops (biomass transfer). Looking past production and employment issues, the livestock sector also provides various services, including the ecosystem services described in this book. This is important because this covers various geographic areas throughout the world. Naturally, this book also serves as a reminder that livestock production, despite its many advantages, still faces significant challenges that limit its contribution to the agroecological transition of agri-food systems. This means livestock farming cannot always reach its full potential as a lever for territorial development.

As a result, livestock farming is often both the problem and the solution, or the culprit and the victim, so to speak. For instance, it is key to the solutions that will be rolled out to address climate change and, at the same, it is often a source of environmental degradation. The animals themselves add to greenhouse gas emissions, while simultaneously enabling carbon fixation in grasslands and pastoral lands; livestock farms can cause soil degradation due to overgrazing and deforestation, but in other situations they facilitate the sustainable management of these same grazing lands and pastures depending on the related practices (degree of intensification). Lastly, they use a large amount of water resources, but they can also help protect this resource when these farms are grassland-based systems, and especially when these grasslands are permanent.

Another growing concern is the health of animals, humans and ecosystems. Comprehensive approaches are therefore required within this context, such as the One Health approach with livestock farming playing a central role, especially given the alarming

zoonotic disease outbreaks. According to the World Organization for Animal Health, 60% of infectious human diseases are in fact animal-borne (FAO *et al.*, 2023).

The central aim of this work is to look past this general observation and to view this set of factors as a potential way to start thinking about the following questions: what are the possible actions that can be taken in the future so that livestock farming can contribute broadly to sustainable development and specifically to the food transition? What is/are the best scale(s) for dealing with this subject matter? Which methodological developments can and should research implement to be able to develop solutions in collaboration with the stakeholders involved?

In this book, the various authors will show that research and methodological tools may play a key role by clarifying the possible future pathways for livestock farming and how it can be integrated within territories. This will help readers better understand how the combination of territorial foresight analysis, scenario modelling-simulation and multicriteria assessment can be used to analyse changes in livestock systems while simultaneously taking economic, social and environmental factors into account.

Some of the more original chapters in this work contain case studies that touch upon a wide variety of themes, methods and scales, from the territory scale to national and supranational scales. Different qualitative and quantitative approaches are introduced for the purpose of anticipating the impacts of climate change, agroecological transitions and/or territorial restructurings. Additionally, methods are described for identifying solutions to conflicts surrounding pastoral herd mobility, the role agri-food production networks play in sectoral and territorial transitions, the sustainable resource use, market dynamics and public policies. It should be noted that although these chapters cannot be used as comprehensive or detailed guides to the various methodologies, each case study provides non-specialist readers with valuable examples and guidelines for the approaches used, and specifically how to set up ways to design solutions and assess their impacts.

Lastly, this book addresses the important question of what the future holds for the societies of tomorrow based on scenarios using foresight and modelling approaches, and especially the adoption of these scenarios in political and decision-making circles. Given the vast array of challenges ahead, we clearly need ambitious public policies that will focus on livestock farming as a lever for territorial development and sustainability. The challenge faced by research is that it needs to propose tools that can galvanize political decision-makers to act in support of public policies that help livestock farms play their full part in raising people's living standards, helping the transition toward more sustainable food systems and safeguarding natural resources.

This book gathers researchers, decision-makers and local stakeholders together, and uses science-based and participatory approaches to provide invaluable insight into the methods and tools that can be used to describe possible futures and, starting today, to help with the necessary transitions.

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General introduction

Aurélie Wilfart, Sandrine Espagnol, Mathieu Vigne, Olivier Mora and Jonathan Vayssières

Global food systems are faced with three key challenges in connection with the environment, food security and human health (Mottet *et al.*, 2020). Livestock farms play a vital role in this, which raises many questions about the different facets that may vary significantly from one region in the world to another.

The United Nations (UN) already called attention to the environmental impacts of livestock farming activities in 2006 in its report, "Livestock's Long Shadow" (Steinfeld *et al.*, 2006); today, these impacts are central to discussions about this sector. The contribution of livestock farming to global environmental impacts varies: ranging from the consumption of non-renewable resources to competition for land use including, of course, greenhouse gas (GHG) emissions. Various Intergovernmental Panel on Climate Change (IPCC) reports emphasize the climate emergency and indicate that anthropogenic GHG emissions must be reduced worldwide. Global food systems account for 34% of all GHG emissions (Crippa *et al.*, 2021). According to the Food and Agriculture Organization's most recent estimates (FAO, 2023), animal production generates 60% of global protein intake (Food and Agriculture Organization of the United Nations, 2022), and 12% of the total GHG emissions from human activities.

In addition to the climate issue, six other planetary boundaries are being exceeded: biodiversity loss, the disruption of nitrogen and phosphorus biogeochemical cycles, land-system change, freshwater use and the introduction of novel entities, such as plastic, into the biosphere, and ocean acidification (Figure i.1).

The use of nitrogen and phosphorus by livestock farming systems drive a substantial amount of international trade which then disrupts the biogeochemical cycles. For instance, Dourmad *et al.* (2019) report that 70% of the nitrogen content in the world's agricultural crops is used as animal feed (in Europe, this percentage goes up to 80%).

Moreover, global livestock populations either directly or indirectly use 75% of agricultural lands for the main purpose of feeding animals (Foley *et al.*, 2011); it has been estimated that all of Europe uses almost as much. However, most of this biomass does not compete with human food. As an example, according to Mottet *et al.* (2017) and Sandström *et al.* (2022), livestock farms around the world consume roughly 6 billion tons of dry matter (DM) in feed, 86% of which is not in competition with human food. Much of these feeding stuffs (60%) are grass and shrub resources consumed by ruminants on marginal land which is not suitable for protein crops that can be consumed by humans (Van Zanten *et al.*, 2015). In France for instance, Dourmad *et al.* (2019) estimate that

although livestock populations either directly (grasslands and harvested fodder) or indirectly (concentrate feeds) use more than half of the usable agricultural area (UAA), this land is first and foremost grassland (3.2 M ha of temporary grasslands and 9.3 M ha of permanent grasslands), followed by land used to grow fodder crops (1.5 M ha) and cereals (1.5 M ha). Lastly, in recent years, the question of water resources has become an important issue. Agriculture represents approximately 90% of global freshwater use and is responsible for close to 70% of global water withdrawals (Govoni *et al.*, 2024). This means that between 30 and 40% of the world's food is produced on irrigated soil (Boulay *et al.*, 2021) whereas livestock farming represents roughly 30 to 40% of global water use (Mekonnen, Hoekstra, 2012; Govoni *et al.*, 2024). The production of raw materials for livestock feed represents 98% of the water footprint for the livestock sector (Mekonnen, Hoekstra, 2012), with rainwater making up 94% of this footprint.

However, this environmental emergency is becoming even more urgent against the background of increasing population growth and increasing global food demand. According to Miller *et al.* (2022), between 1990 and 2018, milk consumption doubled globally (+99%), cheese consumption increased by +56% and yoghurt consumption stayed roughly the same. For reference, the average consumption of unprocessed red meat per person over this same period almost doubled (+88%) worldwide. It is important to note

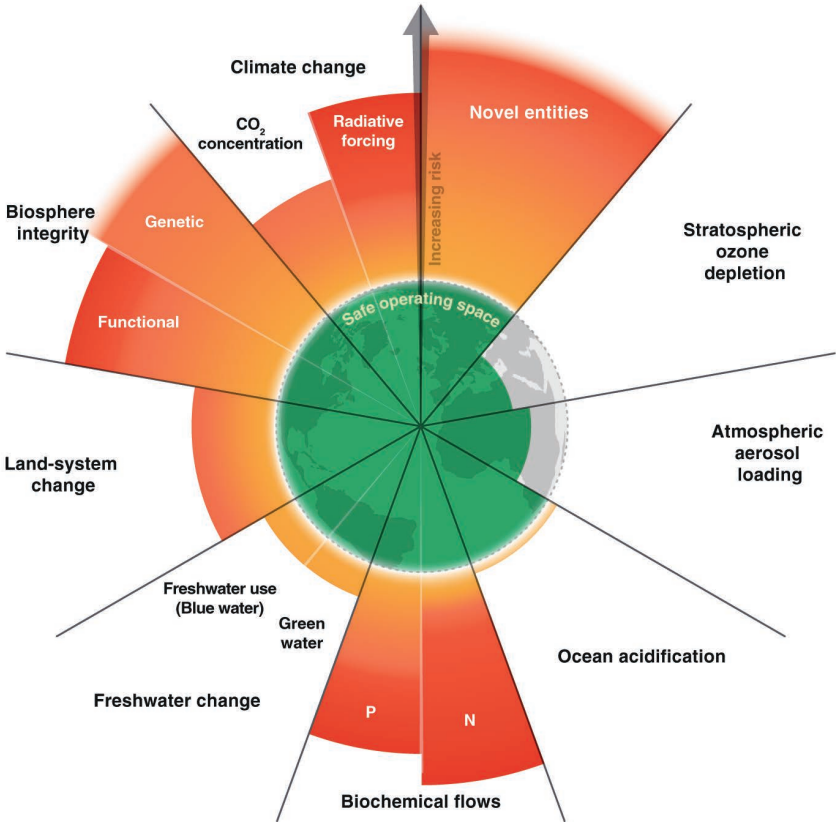

Figure i.1. Planetary boundaries (source: Azote for Stockholm Resilience Centre, based on analysis *in* Sakschewski and Caesar *et al.* 2025, following Steffen *et al.*, 2015).

that this global trend is due to an increase in consumption in only three regions: South-east and East Asia (+266%), Latin America and the Caribbean (+58%) and sub-Saharan Africa (+26%). This consumption is sharply declining in high-income countries but is being substituted by processed meat. In addition to growing environmental awareness, high-income countries are eating less meat, especially in Europe, due to other concerns such as animal welfare (Delanoue, Roguet, 2015), production models (highly criticized off-land and industrial models) and, more recently, the place of livestock farming in territories and food systems.

The resulting public policies in Europe include setting targets and deadlines, and to do so, this means that changes and developments must be carried out in agricultural systems – which of course includes the livestock sector. The European Climate Law and its Carbon Neutrality Roadmap have set a target for Europe to be carbon-neutral (i.e. net-zero greenhouse gas emissions) by 2050. In France, the National Low Carbon Strategy (SNBC for Stratégie Nationale Bas-Carbone) has set objectives to reduce greenhouse gas (GHG) emissions by 2050, with intermediate targets in the short-term (-18% by 2030) and medium-term (-46% by 2050, using 2015 as a reference). These are additional objectives that have been added to the ones set forth in France's Energy Policy Framework from 13 July 2005, known as the POPE Law, which is hoping to achieve a four-fold decrease in GHG emissions between 1990 and 2050 (Martin *et al.*, 2015).

Quite different dynamics are observed in developing countries, particularly in sub-saharan Africa. High population growth rates go hand in hand with nutritional transitions toward animal products (Popkin, 2006). These changes in diet are explained by increasing population sizes in urban areas and rising income levels (Delgado, 2003) and therefore, within this context, the main goal of public policies is to increase livestock productivity and production nationally. This involves taking steps at all levels, such as improving animal genetics, organizing collection and processing systems, introducing new fodder species and, more generally, making changes to fodder systems (Pica-Ciamarra *et al.*, 2013).

This whole context is calling the future of agriculture into question, particularly for livestock farms across the world. Change is necessary. There are several existing levers for change at various scales: from farm holdings and farming households (through the choice of different livestock farming practices and systems) up to the territory level (through the choice of spatial distribution of livestock farms and the choice of local or imported food resources, etc.). At the agricultural system level, we can find partial solutions for some of these challenges through the development of agroecological practices and systems. At the sector level, an important lever has to do with reducing the amount of loss and waste along the whole value chain for animal products. In 2011, the FAO estimated that one-third of the food produced globally is lost or wasted (FAO, 2011) at different stages in the food supply chain depending on the region of the world. In developing countries, food losses mostly occur upstream in the food supply chain due to problems with harvesting and preserving products whereas in industrialized countries, food waste occurs further downstream during the processing steps and due to household behaviour. For consumers, besides reducing food waste, another lever we have at our disposal is our diet itself. For instance, we can choose to support production methods that prioritize local, healthy, fair-trade and environmentally sustainable sectors.

Reducing the percentage of animal proteins in human diets is a public health issue as much as it is an environmental issue for high-income countries, especially OECD (the Organisation for Economic Co-operation and Development) countries. The recommended daily allowance of protein in diets is between 0.6 and 2.2 g/kg of body weight per day, with an average recommendation of approximately 0.83 g/kg of body weight per day for adults in good health (French Agency for Food Safety [AFSSA], 2007; World Health Organization [WHO], 2007). In France, the average person consumes 1.4 g of proteins/kg of body weight per day, which is higher than the recommended average. At present, the ratio between animal-based proteins and plant-based proteins is 60/40 worldwide (FAO, 2022) and 65/35 for France. Based on current estimates, agri-food systems[1] (Figure i.2) represent between one quarter (Barbier *et al.*, 2019) and more than one-third (Crippa *et al.*, 2021) of anthropogenic GHG emissions in France and worldwide, respectively, and animal products have a higher carbon footprint per kilogram than plant-based products. However, more support is needed for these transformations through public policies that meet society's expectations regarding the re-territorialization of agricultural activities (RAA), i.e. shifting from global-scale to local-scale activities, and, more generally, the role that livestock farming plays in global agricultural systems.

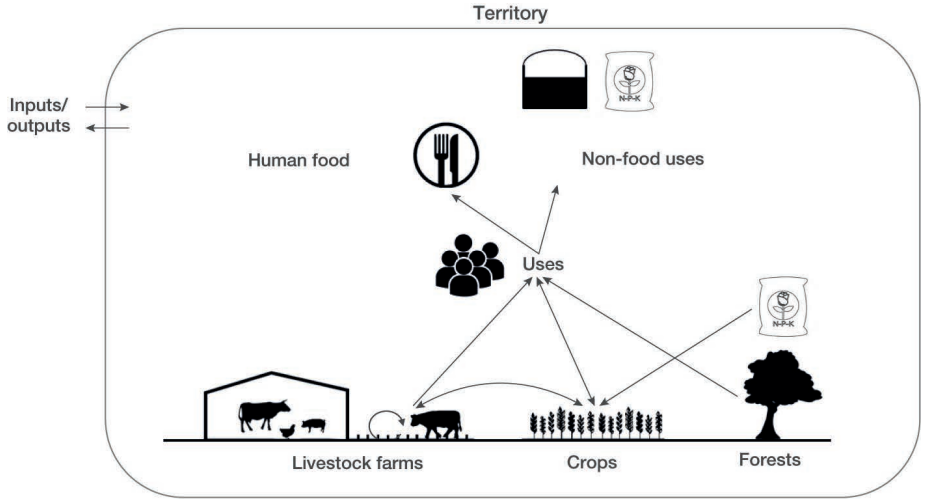

Figure i.2. Simplified representation of the agri-food system.

Foresight analysis generates anticipatory knowledge for research and action purposes which can then be used to shape public discussion and to give decision-makers the information they need without resulting in specific and operational recommendations. It can help steer discussions by laying out the potential impacts of current and future actions and so, to this end, several foresight studies have been conducted to help guide the options for change in agri-food systems. Each study was based on all

1. The term "agri-food system" refers to how people organize themselves socially, in space and in time, to obtain and consume their food (Lamine, 2012) taking into account local and imported resources, the use and processing of co-products and waste, as well as the consumption and possible local production of energy needed for the proper functioning of this system.

or some of the above-mentioned issues and attempted to either qualify scenarios that explore possible futures (exploratory scenarios constructed on trends or disruptions) or to construct scenarios that try to achieve desirable futures that meet predefined objectives, e.g. carbon neutrality (normative scenarios). Foresight studies have an intricate relationship with public policies and can be used in various stages of the public policy cycle (Jacquot, 2019). Normative (or target-seeking) scenarios are developed upstream of transition policies so that the implementation conditions can be examined. The main objectives include addressing the climate emergency and food demand (with an objective to increase food sovereignty within territories) and, more specifically in Europe, to move towards an agroecological and local agriculture that meets society's expectations. Several European countries (France, Denmark, the Netherlands, etc.) are also closely looking at issues regarding nitrates and livestock manures, and there could very well be other issues that arise in the future, such as issues relating to energy or health issues. Consequently, it could become difficult to address several different objectives within the same scenario and therefore, scenario building (or scenario planning) is heavily influenced by how these multiple objectives are considered and prioritized.

This book is based on what was learned during the Researcher School organized by the MAELE joint technology network[2]. It focuses on foresight analyses and assessing transition scenarios for livestock farming in agri-food systems (Figure i.2) in various parts of the world. Given that the challenges, contexts, existing agri-food systems and livestock dynamics at play are so varied, specific foresight studies, modelling and assessments need to be conducted for each specific region. To this end, this book lays the methodological foundation for defining and assessing transition scenarios for livestock farming in agri-food systems using a generic approach that incorporates the challenges and characteristics of agri-food systems in industrialized and developing countries as much as possible.

The first part of this work introduces the foresight approach and illustrates it using four case studies in Brittany, West Africa, France and at the global scale. It also outlines the various steps used, ranging from defining the system, its components and variables, up to building one or more scenarios. The second part focuses on modelling and assessing scenarios at the territorial level. Here, a territory is defined as a given geographical area that accounts for some or all the activities that take place and the various stakeholders involved (see Box 6.1). It presents the flows to be considered, along with the development of multicriteria assessment grids. It also uses two case studies, one in France and one in Europe, to show why foresight studies should be combined with scenario assessments. The third and final part uses an across-the-board approach to build upon the lessons learned from sharing experiences. From a methodological perspective, it formalizes a coupling framework for scenario building and assessments. It also defines the background data matrix needed to conduct foresight analyses as well as to model and assess the resulting scenarios. From a thematic perspective, this last part outlines

2. The objective of the MAELE Joint Technological Network (RMT) is to assess the environmental impacts of livestock systems, in relation to their region and food systems. The goal is to produce a generic and robust scientific and technical foundation that allows us to reflect on the place of livestock farming in future agri-food systems. This would involve connecting livestock systems, territories and food systems around environmental issues.

some of the potential options for change relating to the future of livestock farming in territories and agri-food systems as discussed by policymakers and provides some first thoughts on how policymakers can take over foresight studies.

Consequently, this book addresses methodological questions relating to the construction of scenarios and their modelling-assessment:
– What are the goals?
– Which stakeholders are involved and at what stage(s)?
– What scales and organization levels are taken into consideration?
– What data are needed to perform foresight and to model and assess scenarios?
– What tools are used for simulation models and assessment methods?
– How can we better coordinate foresight analyses so that scenarios can be co-built, and then modelled and assessed?

Part 1

Foresight studies and changes in livestock farming within territories