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SCIENZE E TECNOLOGIE ALIMENTARI

Evaluation of the sustainability level of a dairy and poultry farm: the Response-Inducing Sustainability Evaluation (RISE) method

Tesi in

29597 - Innovazioni nella filiera dei prodotti carnei e ovoprodotti

(67484 - Innovazioni e sicurezza dei prodotti di origine animale c.i.)

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ABSTRACT

Within this paper, various aspects related to the issue of sustainability in the food sector were addressed, focusing on the greenhouse gas emissions derived from livestock production. The increment in population number and wealth is directly related to the growing demand for meat products, which is, in turn, related to an increase in greenhouse gas emissions. Consumers are becoming more and more aware of these environmental issues and, therefore, sustainability factors are becoming even more relevant also from the environmental point of view.

A very useful tool in this field is Response-Inducing Sustainability Evaluation (RISE), a software that allows you to determine the sustainability of a farm under many aspects, like energy consumption, livestock management and soil use. The RISE software processes the information obtained through a questionnaire submitted by the farmer, in which 10 different areas of sustainability in the farm are covered. For each theme, the results are expressed clearly with a score that goes from 0 to 100.

The experimentation discussed in this work included two different projects, one regarding a dairy farm and the other regarding a poultry farm. The first one was conducted on a dairy farm in Germany and the results allowed to highlight the weakest areas of the farm on which recommendations were given for ecological improvement. The second project was conducted on a chicken broiler farm in Italy, on an experimental basis since it was the first time that the software was applied to poultry. The results pointed out the aspects that can be improved in the RISE software in order to make it more suitable for future poultry studies.

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CHAPTER 1

Sustainability in a growing world

1.1 What is Sustainability

The concept of sustainability was originally coined in forestry, where it meant to never harvest more than what the forest yields in new growth (Wiersum, K.F., 1995). While this concept is a relatively new idea, the movement of sustainability as a whole has roots in social justice, conservationism, internationalism, and other past movements with rich histories.

By the end of the twentieth century, many of these ideas had come together in the call for "sustainable development". In 1983, the United Nations appointed the former Norwegian prime minister Gro Harlem Brundtland to run the new World Commission on Environment and Development. After decades of effort to raise living standards through industrialization, many countries were still dealing with extreme poverty. It seemed that economic development at the cost of ecological health and social equity did not lead to long-lasting prosperity. It was clear that the world needed to find a way to harmonize ecology with prosperity. After four years, the "Brundtland Commission" released its final report, also known as "Our Common Future", which defines sustainable development as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED, 1987). The Commission successfully unified environmentalism with social and economic concerns on the world's development agenda.

Sustainability is a holistic approach that considers ecological, social, and economic dimensions, recognizing that all must be considered together to find lasting prosperity. The three pillars of sustainability (United Nations General Assembly, 2005) are:

- *Environmental sustainability*: it means that ecological integrity is maintained, all of earth's environmental systems are kept in balance while natural resources within them are consumed by humans at a rate where they are able to replenish themselves,
- *Economic sustainability:* human communities across the globe are able to maintain their independence and have access to the resources that they require, financial and other, to meet their needs. Economic systems are intact, and activities are available to everyone, such as secure sources of livelihood.
- *Social sustainability:* universal human rights and basic necessities are attainable by all people, who have access to enough resources in order to keep their families and communities healthy and secure. Healthy communities have just leaders who ensure personal, labour, and cultural rights are respected and all people are protected from discrimination.

Considering these three dimensions, the definition of sustainability changed, integrating economic and social aspects, and the one adopted by the United Nations in the Agenda for Development states: *Development is a multidimensional undertaking to achieve a higher quality of life for all people. Economic development, social development, and environmental protection are interdependent and mutually reinforcing components of sustainable development.*

1.2 The right to food

The right to food, set off in Article 25 of the Universal Declaration of Human Rights by the United Nations General Assembly in 1948, has been further elaborated in 2000 and it states that is the right of everyone to have access to safe and nutritious food, consistent with the right to adequate food and the fundamental right of everyone to be free from hunger so as to be able fully to develop and maintain their physical and mental capacities (UN, 2000).

This means that this right is fulfilled only if two conditions are guaranteed at the same time: permanent and unlimited access to food (food security) and availability of adequate quality food (food safety). Even if food security, intended as both food security and food safety, seems to be a simple concept to understand, is not the same when it comes to putting it into practice. Food security is based on three pillars, as FAO stated in 1996:

- *Food availability*: permanently dispose of food in sufficient quantity.
- *Food access*: have the economic resources to obtain food that meets the nutritional needs
- *Food usage*: use food properly, follow basic nutritional and health knowledge, as well as have adequate water and hygienic practices.

Despite the big improvements made toward the Sustainability Development Goals to eradicate hunger and reduce poverty, we are still far from succeeding.

Overall, and across most regions, the prevalence of hunger has fallen since the millennium. It is safe to say that we are seeing a falling – although variable – trend over the last few decades, the rate has gone from 13,3% in 2001 to 8,9% in 2017. The lowest point has been reached in 2013, with 642,9 million people undernourished. This latest increase in hunger levels is largely a result of increases in Sub-Saharan Africa and small increases in the Middle East & North African populations. The UN FAO has linked this increase in undernourishment in particular to the rising extent of conflict-affected countries, which is often a leading cause of famine, and climate-related factors such as floods, rising temperatures, and wildfires. The global financial crisis has also made adjustments to the dynamics of poverty and, consequently, the problems of hunger challenging (Lipton and Saghai, 2017).

A specific need to be made in order to understand the global development in this field, which is that historical data on hunger ad malnourishment are lacking. The most concrete and well-established sources of data begin in 1990, the year in which our global progress indicators on hunger reduction started to be tracked regularly. The reason is that the Millennium Development Goals

(MDGs), and the subsequent Sustainable Development Goals (SDGs), refer to this year. However, to provide some sense of how malnutrition rates have changed over a longer timeframe, it was possible to extend the latest data on undernourishment backward with some estimates data sourced from FAO State of Food Insecurity in the World reports of 2006 and 2010. Previous data were not taken into consideration due to the fact that they were considering only developing countries and not the world as a whole (FAO, 2015).

Taking into account the uncertainty of this old data, it is shown in figure 1.1 the trend, which is consistently decreasing.

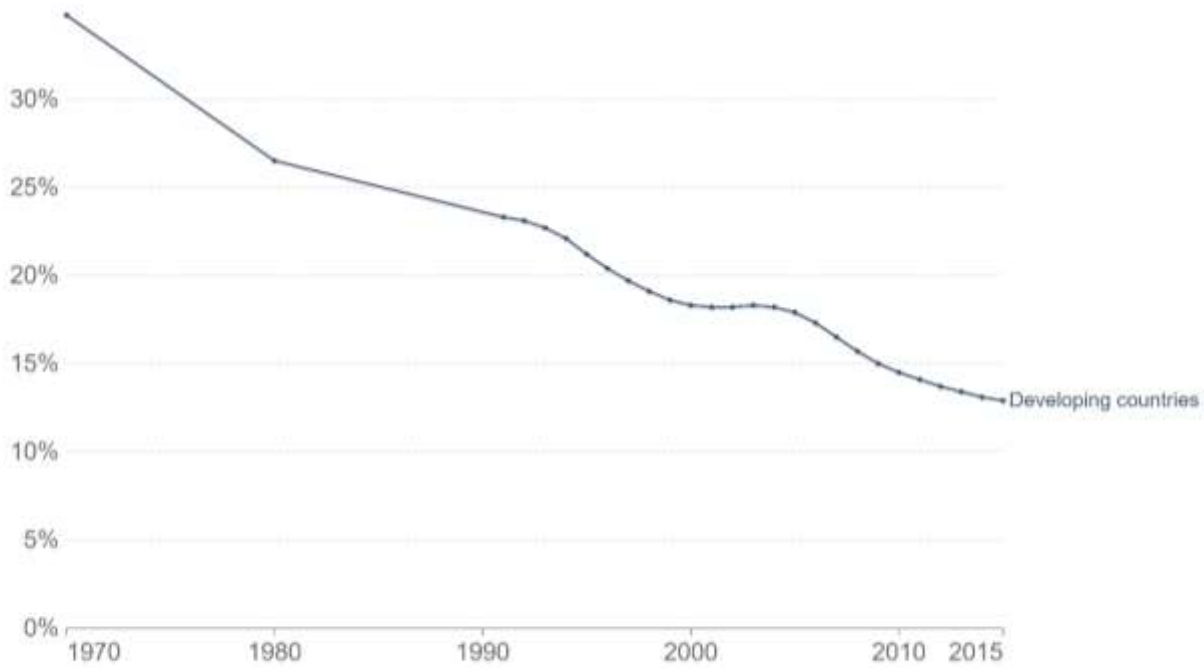

Figure 1.1: prevalence of undernourishment in developing countries from 1970 to 2015 (Our World in Data, 2016)

Food insecurity is defined by the UN FAO as the "situation when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life". It can be caused by a number of factors, including the unavailability of food, unaffordable food, inadequate quality and quantity of food, and unequal distribution of food between household members. Food insecurity is one of the major causes of poor nutrition.

There are several levels of food insecurity: moderate food insecurity is generally associated with the inability to regularly eat healthy and nutritious diets and a high prevalence of this data is, therefore, an important indicator of poor dietary quality, and the development of health outcomes such as micronutrient deficiencies, while severe food insecurity is more strongly related to insufficient quantity of food (energy) and therefore strongly related to undernourishment or hunger.

Still, in 2018, 9,2% of the world population was defined as severely food insecure. As a share of the population, food insecurity is highest in Sub-Saharan Africa where nearly one-third are defined as severely insecure. Globally, around 697 million were severely food insecure in 2018, more than half of those living in this condition were in Asia; nearly 40% were in Africa and the remaining 10% were split between the Americas, Europe, and Oceania. Worldwide, one in four suffered from moderate or severe food insecurity in 2017.

It is important to keep in mind that the global problem of hunger cannot be solved simply by increasing productivity since hunger usually does not occur because there were no grain stocks in the world, but because of the low income of the population in most developing countries, where food products were inaccessible for many people (Prosekov & Ivanova, 2018).

1.3 A growing world

The global population grew very slowly up to 1700, with only 0.04% per year. In the many millennia up to that point in history, very high mortality of children counteracted high fertility and the world was in the first stage of the demographic transition. Once health improved and mortality declined things changed quickly, particularly over the course of the 20th century. In fact, over the last 100 years global population more than quadrupled and, as we see in the chart, the rise of the global population got steeper, and it is still growing fast: every year 140 million babies are born, and 58 million people die – the difference is the number of people that we add to the world population in a year: 82 million.

In purple, in figure 1.2, you see the annual population growth rate of the global population. Peak population growth was reached in 1968 with an annual growth of 2.1%. Since then, the increase of the world population has slowed and today grows by just over 1% per year. The world has entered the last phase of the demographic transition, and this means we will not repeat the past. The global population has quadrupled over the course of the 20th century, but it will not double anymore over the course of this century.

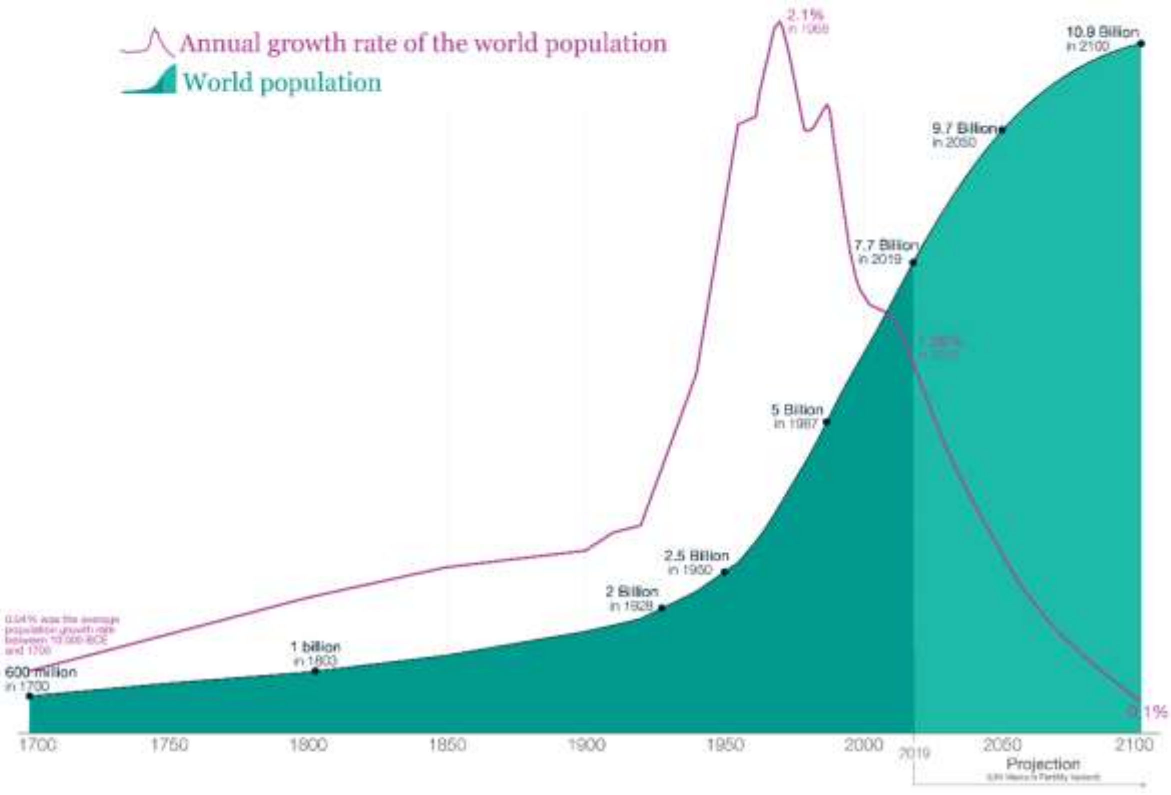

Figure 1.2: World population growth from 1700 to 2100 (Our World in Data, 2019)

The chart in figure 1.2 also shows how the United Nations envision the slow ending of the global demographic transition. As population growth continues to decline, the curve representing the world population is getting less and less steep. By the end of the century – when global population growth will have fallen to 0.1% according to the UN's projection – the world will be very close to the end of the demographic transition. It is hard to know the population dynamics beyond 2100, but the world population will reach a size that compared to humanity's history will be extraordinary. The change in the world population is determined by two metrics: the number of babies born, and the number of people dying. The new equilibrium will be different from the one in the past when it was the very high mortality that kept population growth in check. In the new balance, it will be low fertility that keeps population changes small. Population projections show that the yearly number of births will remain at around 140 million per year over the coming decades and is then expected to slowly decline in the second half of the century. At the same time, as the world population ages, the annual number of deaths is expected to continue to increase in the coming decades until it reaches a similar annual number as the global births towards the end of the century. As the number of births is expected to slowly fall and the number of deaths to rise the global population growth rate will continue to fall. This is when the world population will stop to increase in the future.

This is an extraordinary moment in global history. In the past, child mortality was extremely high, and only two children per woman reached adulthood, since if more had survived the population size would have not been stable. This also means that the extended family with many children, that we often associate with the past, was only a reality for a glimpse in time. Only a few generations during the population boom lived in families with many children, before and after that time two children were the norm. The future will resemble our past, except for the fact that children are not dying, but are never born in the first place.

The actual world population is 7,7 billion people, and it seems that will be reaching 10,9 billion by 2100, according to FAO projections.

1.4 Facing reality

In figure 1.3, we see the partition of the global area today. Most of the Earth’s surface is covered by oceans and only 29% is land surface. Of this percentage, 10% is covered by glaciers, and a further 19% is barren land, such as deserts, dry salt flats, beaches, sand dunes, and exposed rocks. The rest represents what we call ‘habitable land’. Half of all habitable land is used for agriculture (Ellis et. al., 2010), 37% for forests; 11% for shrubs and grasslands;

1% for freshwater coverage; and just the remaining 1% for the urban areas which include cities, towns, villages, roads, and other human infrastructure.

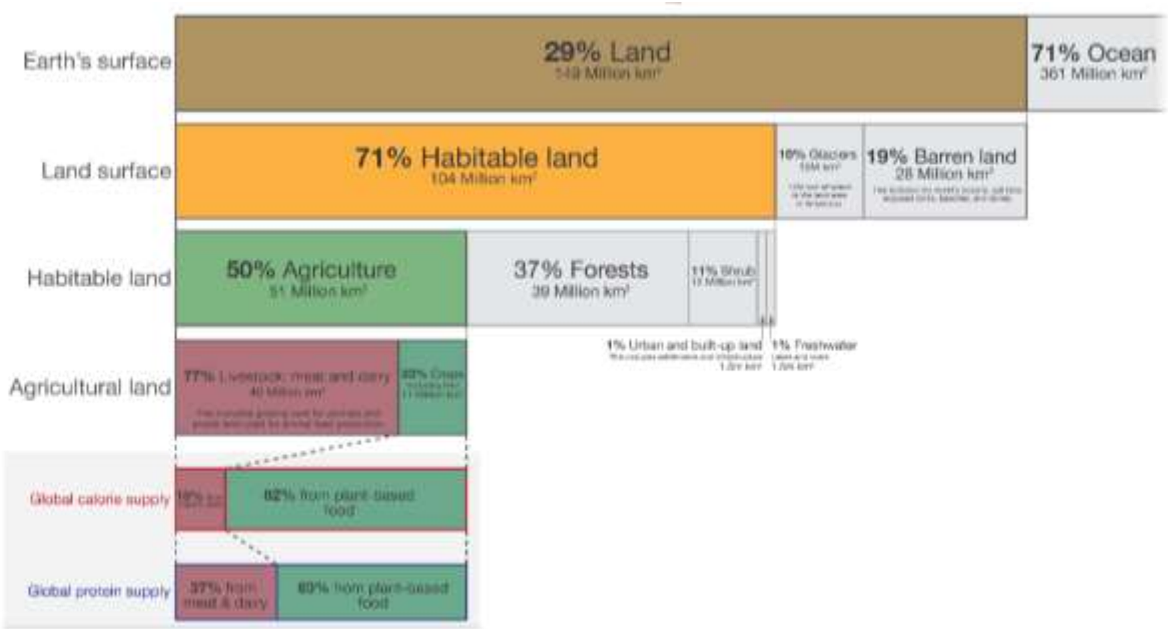

Figure 1.3: Global land use for food production (Our World in Data, 2019)

There is also a highly unequal distribution of land use between livestock and crops for human consumption. If we combine pastures used for grazing with land used to grow crops for animal feed, livestock accounts for 77% of global farming land. While livestock takes up most of the world's agricultural land it only produces 18% of the world's calories and 37% of total protein (Poore & Nemecek, 2018).

The use of the agricultural area, about 4,9 million hectares, is divided into three categories: arable land (28% of the global agricultural area), permanent crops (3%), and permanent meadows and pastures (69%).

The FAO definition for arable land is land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens, and land temporarily fallow. Fallow land refers to cultivated land that is not seeded for one, or more, growing seasons, up to a maximum of five years.

Permanent crops are divided into temporary and permanent crops. Permanent crops are sown or planted once, and then occupy the land for some years and need not be replanted after each annual harvest. This category includes flowering shrubs, fruit trees, nut trees, and vines, but excludes trees grown for wood or timber.

Instead, permanent meadows and pastures are defined as land used permanently, for five years or more, to grow herbaceous forage crops, either cultivated or growing wild (i.e., wild prairie or grazing land).

There are two main uses of agricultural land: arable farming (land dedicated to growing crops), and pastureland (which includes meadows and pastures used for livestock rearing). For most countries, land use for livestock grazing is dominant relative to arable farming. Land dedicated to cropland is typically below 20% in most of the world, but there are countries such as India, Bangladesh, Ukraine, and Denmark that dedicated more than half of their total land area to cropland in 2015.

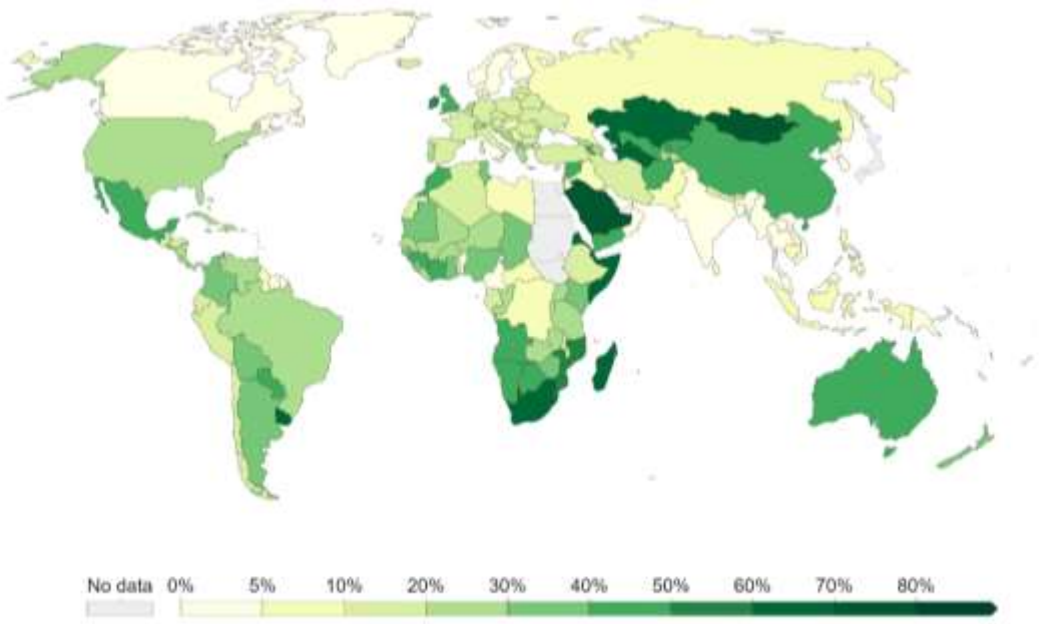

Figure 1.5: Share of land used for permanent meadows and pastures (Our World in Data, 2017)

In contrast to arable farming, land use for livestock in Europe and South Asia is typically less than 20%. However, most continental regions have countries where pastureland reaches close to half of the total land area, particularly in Central Asia, including Mongolia, Kazakhstan, and Turkmenistan, this can reach up to 70%, as we can see in figure 1.5. This percentage is due to the fact that livestock farming can take place across a range of diverse climatic and environmental regions, from temperate regions to hilly and semi-arid terrain, meaning that this type of agriculture is potentially less geographically constrained than arable farming.

1.5 Man and meat

Human beings have a long history of consuming meat and meat products. Meat is one of the most valuable foods from a nutritional viewpoint. Although there are implications about the correlation between meat and some disorders, the role of meat in the human diet during evolution should not be neglected. Studies have shown that the diet of early hominin species was mainly based on plants, fruits, seeds, grasses, and tubers, supplemented with some animal foods. Results of paleontological and archaeological research supported the theory that the incorporation of larger amounts of animal proteins started with the earliest *Homo*, about 1.5 million years ago (Djekic & Tomasevic, 2019). It is supposed that *H. habilis* obtained meat from scavenging and a smaller part by hunting, while hunting was the predominant method for *H. erectus* to obtain animal proteins, and it appears to be a major adaptive shift in human evolution (Baltic, & Boskovic, 2015), also because the fire could be used and manipulate. Hunting and meat-eating resulted in increased body size.

As meat becomes more common in nutrition, it was inevitable for changes in the digestive tract to occur, in order to adapt to the new diet and since then, humanity is consuming meat from different types of animals, and meat consumption became part of our culture. Proteins provide energy and are essential for growth, development, maintenance, and the repair of the tissues. Meat protein contains eight essential amino acids and histidine, which is considered to be an additional essential amino acid for children (Wyness et al., 2011). Meat also contains taurine, essential in newborn infants who are less able to synthesize this amino acid from cysteine, so they get it through breast milk, which is why meat is important in mothers' nutrition. Taurine exhibits antioxidant and anti-inflammatory activity, which can be related to cardiovascular disease prevention and is almost exclusively found in animal products. Meat is also a rich source of many micronutrients, especially iron, but despite its nutritional value, consumption of meat, especially red meat, is linked to numerous diseases and disorders: colorectal cancer is the cancer type most often associated with red meat consumption. Moreover, fat, heterocyclic aromatic amines (HAAs), polycyclic aromatic hydrocarbons (PAHs), N-nitroso compounds (NOc) and heme iron are substances isolated from red meat and which are considered to influence the occurrence of cancer (Baena Ruiz & Salinas Hernández, 2014). Many studies indicate that fresh meat itself is not carcinogenic and that the risk of cancer is mainly associated with cooking methods and carcinogens produced during meat processing and preparation. Although meat processing, especially at high temperatures, reduces the risk of foodborne diseases, those practices may cause the formation of chemical compounds which can be carcinogens and mutagens (Berjia et al., 2014).

That being said, the inclusion of meat in the diet is indubitably an important factor in human evolution. The constant use of fire to cook food and the phasing out of hunting and harvesting practices in favour of farming laid the basis for the birth of agriculture. With it, mankind changed not only his lifestyle, which from nomadic became stable but also his eating habits and the natural environment where he settled. The practices of cultivation are accompanied by the first forms of animal domestication, selected and bred to help work in the fields and to provide food, wool, and leather. The foundations of what is now known as the “Mediterranean Diet” were created: from now on people will follow a diet based on bread, cereals, fruits, vegetables, fish and meat.

Over the centuries, the influences of first the Roman-barbarians agricultural, forestry and sheep-farming systems offered a varied diet and allowed meat to be accessible to the entire population, successively one witnessed the formation of a gap between the rich and varied food supply of nobles in the cities, and the rural population, where economic hardship relegate the consumption of meat only to festive occasions. The culinary culture of the countryside develops, consequently giving priority to cereals, bread, legumes and vegetables, and inventing recipes to reuse all the cuts of meat and minimising waste.

The shortage of meat in the diet of the rural population remains constant until the early twentieth century. It is the strong economic growth that led to an increase in meat consumption from this part of the population, becoming the symbol of freedom from misery and poverty.

To meet the growth in population and food consumption meat production is intensified: the food industry is structured to cope with the demand and farms become more and more efficient in production (Bernardi et al., 2019).

Today different trends influence the choice to eat or not to eat meat. Meat nutritional composition still makes an important contribution to human diets, affecting proper growth and physical and cognitive development. However, awareness of animal welfare, environmental pollution and some disorders and diseases linked to meat production and consumption have created a trend of meat avoidance. Flexitarians, person who eats mostly as a vegetarian but sometimes includes meat, fish, or poultry, are more and more numerous. They have different moral drivers than vegetarians raising concerns about animal welfare more than full-time meat eaters but less than vegetarians (De Backer & Hudders 2015). Taking into account the vegetarians and other voluntary dietary habits such as veganism (exclusion from animal products), raw foodism (dietary practice of eating only uncooked, unprocessed foods), fruitarianism (a diet that consists entirely or primarily of fruits and possibly nuts and seeds, without any animal products), and various religious restrictions, we can say that a large majority of the human population eat meat regularly or occasionally. In summary, humanity used to and still relies on meat and meat products (Baltic & Boskovic, 2015).

Along with increasing meat production, increased demand for animal protein highlights the important role of meat in the global food supply. In the next years, a dramatic increase in the demand for products of animal origin is expected to occur due to several aspects. First, the exponential growth of the world’s population, second, the process of urbanization, which will likely lead to a concentration of up to 60% of the population in urban areas by 2030 (Pretty, 2008); third, the increase of income of a large part of the population in emergent countries, such as China and India, will result in a sharp increase in individual demand of animal products (Pulina et. al., 2011), and fourth, regard trade liberalization and globalization of food systems (Delgado 2003).

So far, the increased demand for food has been supplied by agriculture due to the improvement of techniques and the use of modern technologies. An example can be the increase in cultivated land areas, where possible, the increase of the fertility of lands using biological resources of sea and ocean waters, the use of solar energy, and advances in genetics and breeding for improving crops, and breeding more productive breeds of animals (Prosekov & Ivanova, 2018).

Despite that, unequal food distribution throughout the world has led to almost 1 billion undernourished or starving people in the first decade of the twenty-first century. In the future, it will be necessary to achieve a sustainable supply of food, especially of animal origin, because land and other production factors are not unlimited resources. Indeed, the large increase in the world’s population amplified humanity’s impact on the natural environment and providing space, food, and resources in a way that is sustainable into the distant future is without question one of the biggest and most serious challenges for our generation.

1.6 Growing meat demand

The growth of demand is especially relevant for meat, meat products, and animal-derived foods. In particular, global meat production has increased rapidly over the past 50 years. In this period of time total production has more than quadrupled, going from 71 million tonnes in 1961 to 341,16 million tonnes in 2018, as shown in figure 1.6.

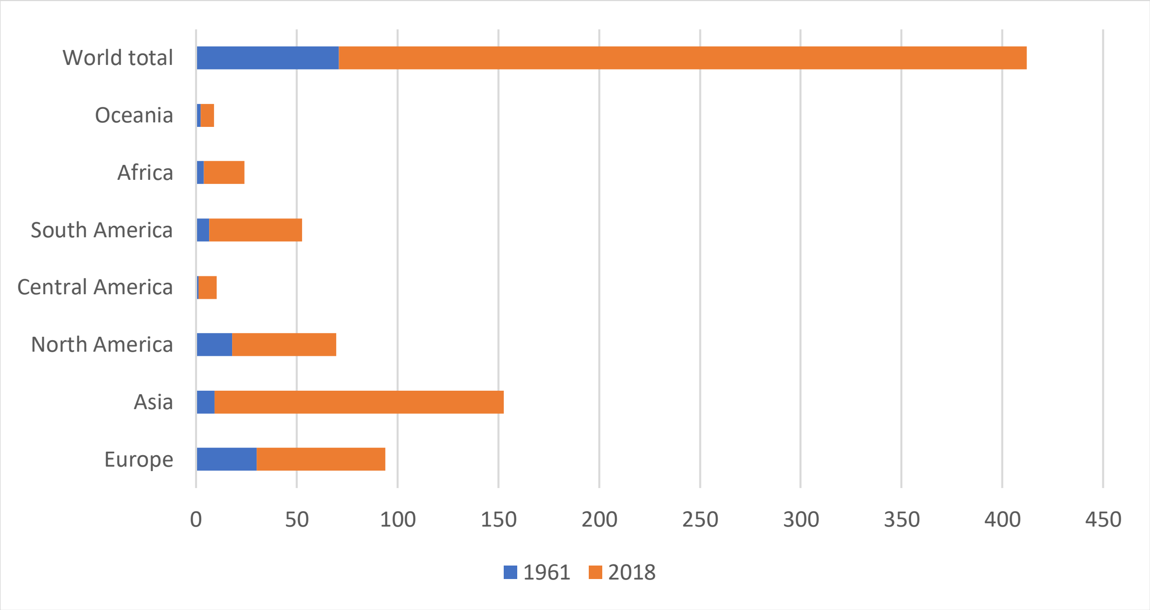

Figure 1.6: World global meat production in 1961 and 2018 (adapted from FAO, 2019)

Regionally, Asia is the largest meat producer, accounting for around 40-45% of total meat production. This regional distribution has changed significantly in recent decades. In 1961, Europe and North America were the dominant meat producers, accounting for 42% and 25% respectively, whereas Asia produced only 12%. Nowadays the rates are reversed: Asia has become the biggest meat productor with a rate of 42%, South America also got its rehearsal, increasing its production up to 15%; while Europe and North America hit only 15% and 19% respectively.

One of the strongest determinants of how much meat people eat is how rich they are. As a global average, per capita meat consumption has increased by approximately 20 kilograms since 1961; nowadays the average person consumes around 43 kilograms of meat. This increase means that the total meat production has been growing at a much faster rate than the population growth. It is important to also notice that the distribution of meat types consumed varies significantly across the world, as shown in figure 1.7; some countries such as the USA, Brazil, or Argentina consume more beef meat or poultry meat, instead, China, Italy, and Germany consume more pig meat, or even middle east countries consume more sheep and goat meat.

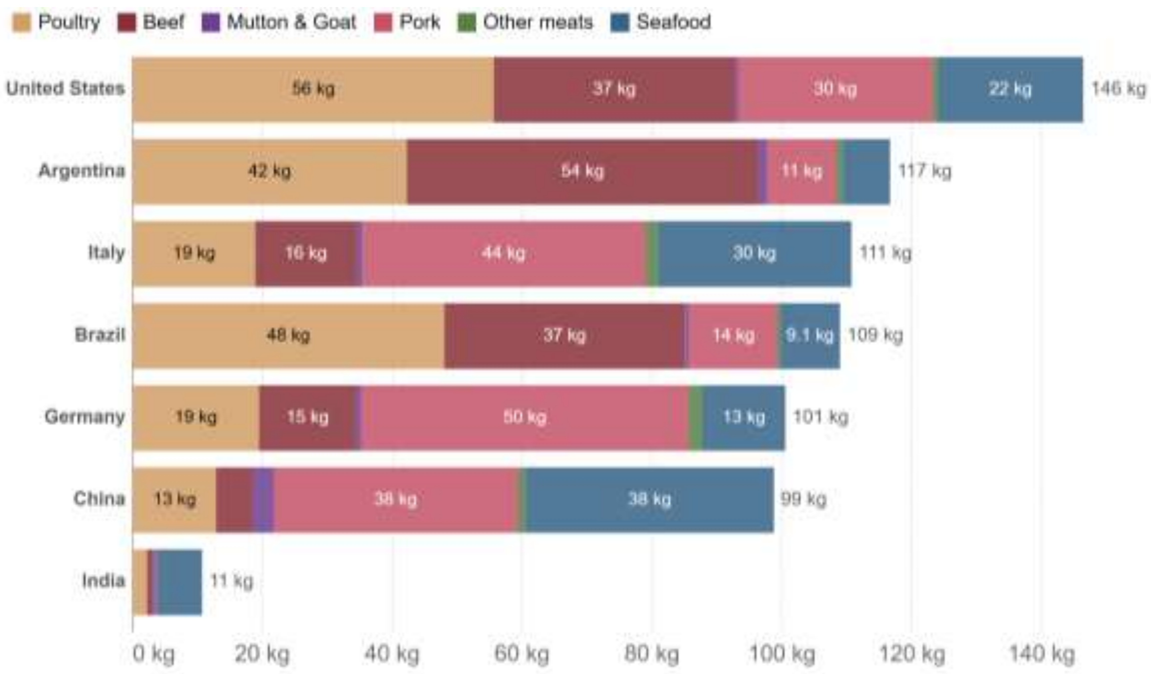

Figure 1.7: meat consumption per capita by type (Our World in Data, 2017)

Trends in meat consumption suggest that the influence of factors such as income and price will decline over time and that saturation in meat consumption may have been reached in many markets. Thus, other factors, such as quality, will become more significant in influencing consumer choice in developed countries. People are becoming more interested in meat production systems, animal welfare, food safety, and other quality-related matters and this is likely to have an effect on meat consumption patterns in the future (Henchion et al., 2014). It will be essential for the meat industry to fully understand how consumers perceive quality and how such perceptions influence their choices, and to determine the most important quality attributes they need to maintain and enhance in existing and new meat products (Troy & Kerry, 2010).

CHAPTER 2

The impact of the food-chain

2.1 Greenhouse gas emissions from the food industry

The expansion of agriculture has been one of humanity's largest impacts on the environment. It has transformed habitats and is one of the greatest pressures on biodiversity since food production requires dedicated space, water, and energy.

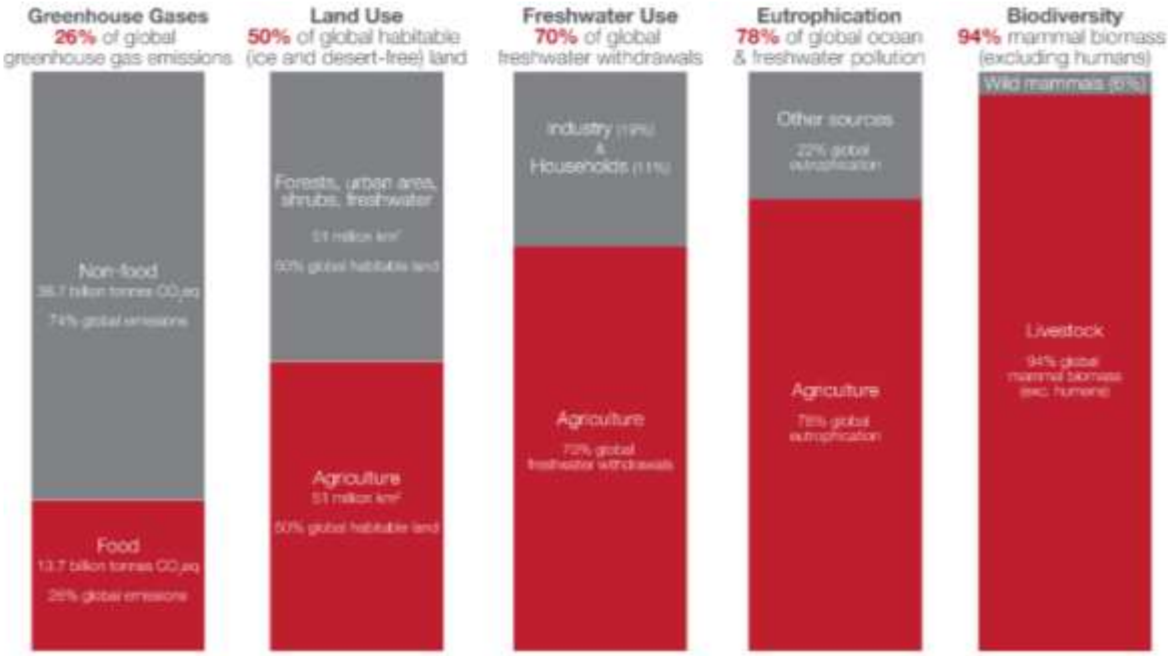

Figure 2.1: Environmental impacts of food and agriculture (Our World in Data, 2018)

Figure 2.1 shows a summary of some of the main global impacts. As shown before, half of the world's habitable land is used for agriculture and 70% of global freshwater withdrawals are used for agriculture. In figure 2.1, it can also be noticed that food accounts for over a quarter (26%) of global greenhouse gas emissions; 78% of the global ocean and freshwater eutrophication, meaning the pollution of waterways with nutrient-rich pollutants, is caused by agriculture; and most of all, 94% of mammal biomass (excluding humans) is livestock. This means livestock by far outweighed wild mammals (Poore & Nemecek, 2018).

When it comes to tackling climate change via food, the focus tends to be on clean energy solutions, such as the deployment of renewable or nuclear energy; improvements in energy efficiency; or transition to low-carbon transport. Indeed, energy, whether in the form of electricity, heat, transport or industrial processes, account for the majority of greenhouse gas (GHG) emissions, with a rate of 76% (IPCC,2014). Furthermore, the global food system, which encompasses production, and post-farm stages such as processing, and distribution is also a key contributor to emissions, but it is a problem for which we do not have viable technological solutions yet.

Food, therefore, is the heart of the change when trying to tackle climate change because is directly relatable to water stress, pollution, and land usage, and it is the most important aspect that we, as consumers, can decide on.

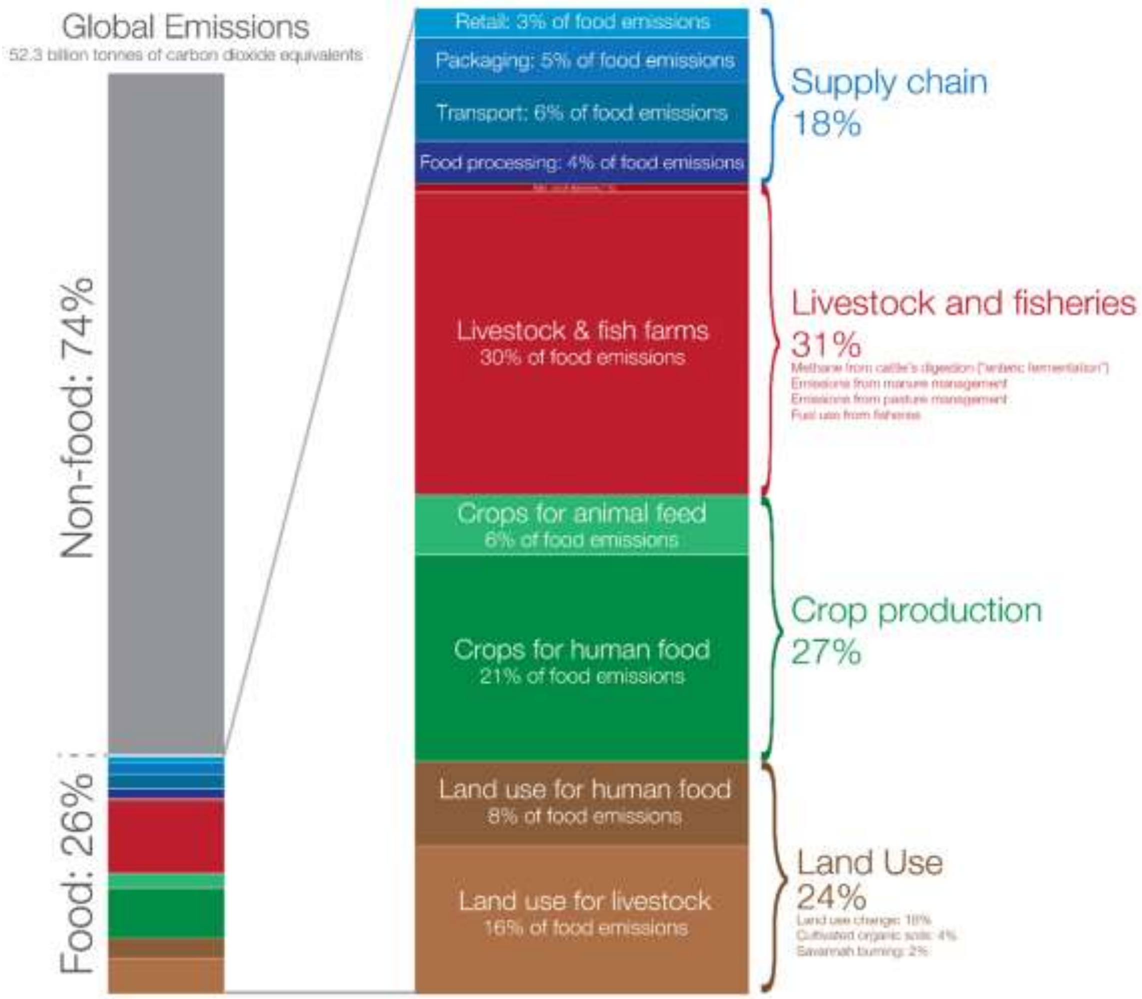

Figure 2.2: Global greenhouse gas emissions from food production (Our World in Data, 2018)

In figure 2.2, based on data from the analysis by Joseph Poore and Thomas Nemecek (2018), we can see how food is responsible for approximately 26% of global GHG emissions and it can go up to 34% if we also consider the post-retail emissions, derived from food preparation and food waste. Breaking down this component we can evidence four key elements to consider when trying to quantify food GHG emissions:

1. *Livestock & fisheries (31%):* livestock considers all animals raised for meat, dairy, eggs and seafood production, which contribute to emissions in several ways. In particular, the animals contribute to the emissions of CO_2 with the respiration, with the CH_4 of the ruminal and enteric fermentation and with the emissions of CO_2, CH_4 and N_2O produced by the chemical reactions and the biological processes that take place in the wastewater (Pulina et. al., 2011).

   Manure management, pasture management, and fuel consumption from fishing vessels also contribute to this category. This value of emissions relates to on-farm production emissions only, which means that it does not include land-use change or supply chain emissions from the production of crops for animal feed.
2. *Crop production (27%):* the main part of this category, 21%, comes from crop production for direct human consumption, and 6% comes from animal feed production. Here are considered the direct emissions that result from agricultural production, including elements such as the release of nitrous oxide from fertilizers and manure, methane emissions from rice production, and carbon dioxide from agricultural machinery.
3. *Land use (24%):* the percentage of the emissions resulting from land use for livestock Is exactly twice the rate derived from crops for human consumption. Agricultural expansion results in the conversion of forests, grasslands and other carbon sink into cropland or pasture resulting in carbon dioxide emissions.
4. *Supply chains (18%):* food processing, meaning all the stages needed to convert produce from the farm into final products, transport, packaging

> and retail, require energy and resource inputs. Many assume that eating local is key to a low-carbon diet, however, transport emissions are often a very small percentage of food's total emissions, only 6% globally. Although supply chain emissions may seem high, the essential way to reduce emissions is to prevent food waste. Food waste emissions are large: is estimated that one-quarter of emissions (about 3.3 billion tonnes of CO_2eq) from food production end up as wastage either from supply chain losses or consumers (Gustavsson et al., 2013). Durable packaging, refrigeration and food processing can all help to prevent food waste.

Reducing emissions from food production will be one of our greatest challenges in the coming decades since the ways in which is possible to decarbonize agriculture are less clear than the many aspects of energy production, where viable opportunities for upscaling low-carbon energy are available and quite easy to source. In agriculture many inputs are needed, such as fertilizers to meet growing food demands, changes to diets, food waste reduction, improvements in agricultural efficiency, and technologies that make low-carbon food alternatives scalable and affordable; at the same time, it is impossible to stop cattle from producing methane.

As stated before, food production is responsible for one-quarter of the world's greenhouse gas emissions and there is a growing awareness that our diet and food choices have a significant impact on our carbon footprint.

To actively reduce one's carbon footprint is often recommended to eat local, but while it might make sense intuitively, since transport does lead to emissions, it would only have a significant impact if transport was responsible for a large share of food's final carbon footprint, and as we have seen in figure 2.2, for most foods, this is not the case. GHG emissions from transportation represent a very small amount of the emissions.

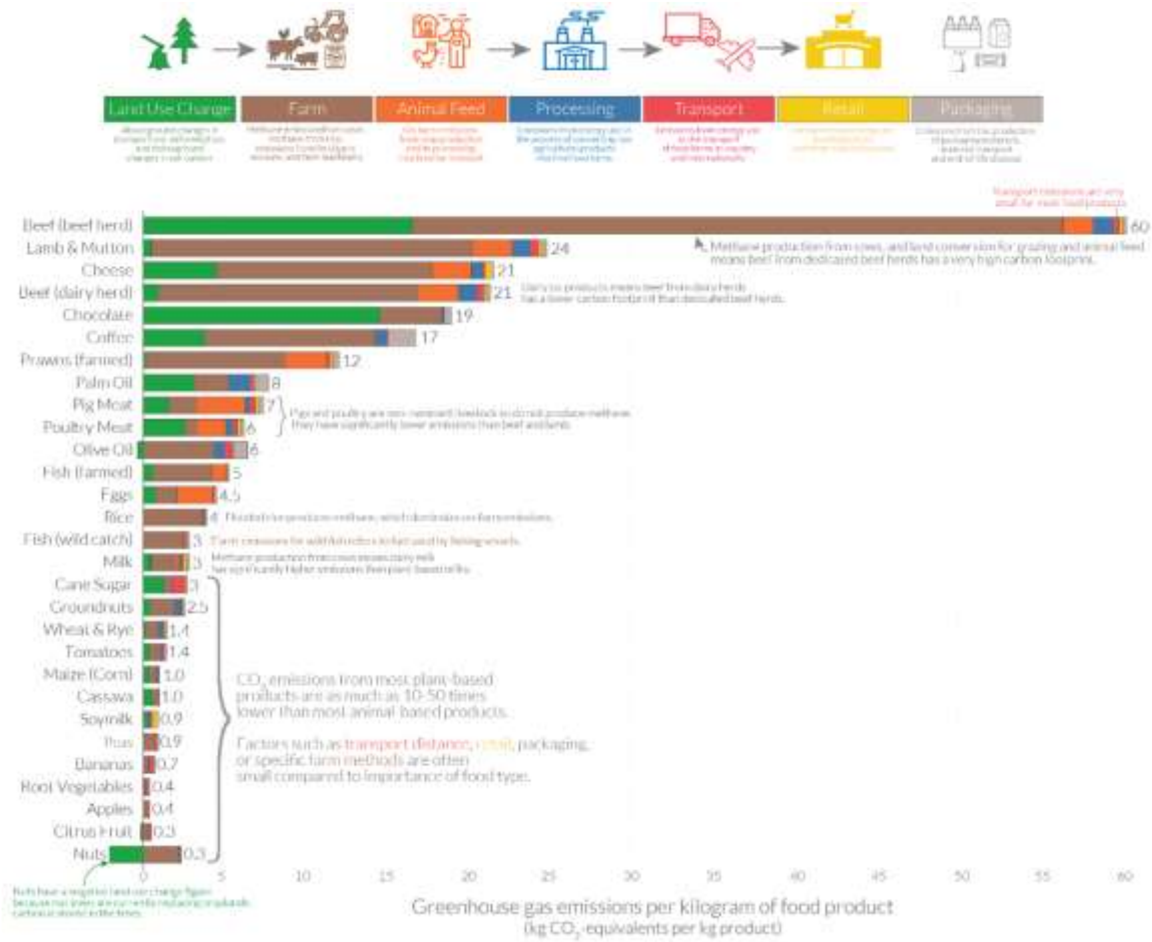

Figure 2.3: Greenhouse gas emissions across the supply chain (Our World in Data, 2018)

In a study by Poore & Nemecek in 2018, the authors looked at data across more than 38,000 commercial farms in 119 countries and stated the total GHG emissions per kilogram of food product, shown in figure 2.3.

CO_2 is the most important greenhouse gas, but not the only one, agriculture is also a large source of methane and nitrous oxide. This metric takes account of all the greenhouse gases, converting them into carbon dioxide equivalents for practicality.

The most important insight from this study is that there are massive differences in the GHG emissions of different foods, especially if we compare animal products and vegetables. For example, producing a kilogram of beef emits 60 kilograms of greenhouse gases (CO_2-equivalents), while peas emit just 1 kilogram per kg. Overall, animal-based foods tend to have a higher footprint than plant-based. Lamb and cheese both emit more than 20 kilograms of CO_2-equivalents per kilogram. Poultry and pork have lower footprints but are still higher than most plant-based foods, at 6 and 7 kg CO_2-equivalents, respectively.

Figure 2.3 also breaks down the origin of these GHG emissions. It can be noticed that for most foods, and particularly the largest emitters, most GHG emissions result from land-use change (shown in green), and from processes at the farm stage (shown in brown). Farm-stage emissions include processes such as the application of fertilizers, both organic and synthetic, and enteric fermentation. Combined, land use and farm-stage emissions account for more than 80% of the footprint for most foods. Transport is a small contributor to emissions. For most food products, it accounts for less than 10%, and it's much smaller for the largest GHG emitters, moreover, all the stages in the supply chain after the food left the farm, such as processing, transport, retail and packaging, mostly account for a small share of emissions. This is true except for one exception: products which travel by air, that tend to be foods which are highly perishable (such as asparagus, green beans, and berries). This means they need to be eaten soon after they've been harvested and, in this case, transport by boat is too slow, leaving air travel as the only option increasing emissions: aeroplane travels emit 50 times more CO_2eq than boat per tonne-kilometre.

MacLeod et al. in a study from 2013 also stated that there is much more variation in the footprints of beef, lamb, dairy, and aquaculture production than for other foods because there are large differences in the intensity and practices used in ruminant livestock, and fish farming across the world. This is different from poultry and pig farming, which for the most part is produced intensively in industrial-farm settings which are very similar wherever they are in the world. One factor that explains a lot about the carbon footprint variation for beef production is whether it is sourced from a dairy herd, where the cattle also produce milk or a herd dedicated to beef production. Just 44% of the world's beef comes from the dairy sector but it produces 60% lower emissions because its footprint is shared with dairy co-products.

Another factor that plays a role in the large variations in beef, lamb and aquaculture carbon footprints is geography. Farming approaches are often adopted in line with local conditions such as soil fertility, terrain, and temperature. Therefore, opportunities for food producers to reduce emissions are therefore very specific to the local conditions.

Eventually, there are some general recommendations that are clear from this research that can be implemented, such as improving degraded pasture, improving lifetime animal productivity, increasing oxygen flow in aquaculture ponds, particularly in warm climates, and avoiding the conversion of forests and peatlands for agriculture. Land-use change can also play a large role in the final emissions, and good pasture quality is also important even if the climate has a strong impact on it.

2.2 Reducing the carbon footprint

People across the world are becoming increasingly concerned about climate change. A survey conducted by the Pew Research Center in 2018 has shown that 8-in-10 people see climate change as a major threat to their country.

To reduce the emissions from food there is massive scope for both consumers and producers. Agriculture can improve in many aspects, starting with the study of a suitable economic model to ensure both environmental sustainability and acceptable living conditions for the population. Understanding and adopting the best farm and land management practices can mitigate the highest impacts of production, since the world is not likely to abandon livestock farming completely, at least not any time soon. It can also act through the use of more innovative technologies, e.g. pesticides, fertilizers and GMOs (especially for plant-based productions). These, in particular, will play a fundamental role in the agriculture of the future and, as a result, will affect the opportunities and limitations of organic, conventional and mixed farming systems.

Any proposal should take into account the fact that our planet does not have the reserve of land necessary for the continuous expansion of agriculture. In addition, at this time, there is a strong propensity to convert land from conventional agriculture/livestock to organic, since most of the public opinion of developed countries believes that the first type is less safe than the biological one. It is true that fewer pesticides, antibiotics and substances potentially harmful to the soil are used in organic farming, so theoretically it should be the best choice, however, organic farming is less productive than conventional farming, both in plant and animal production, and this is not in line with the increasing demand in this sector (Pulina et.al, 2011).

There are several reasons why it can be almost certain that meat demand will continue to grow. First, meat production is an important source of income for many, and secondly, it can also be a key source of nutrition in local settings, particularly in lower-income countries where diets lack diversity and small amounts of meat and dairy are an essential source of protein and micronutrients.

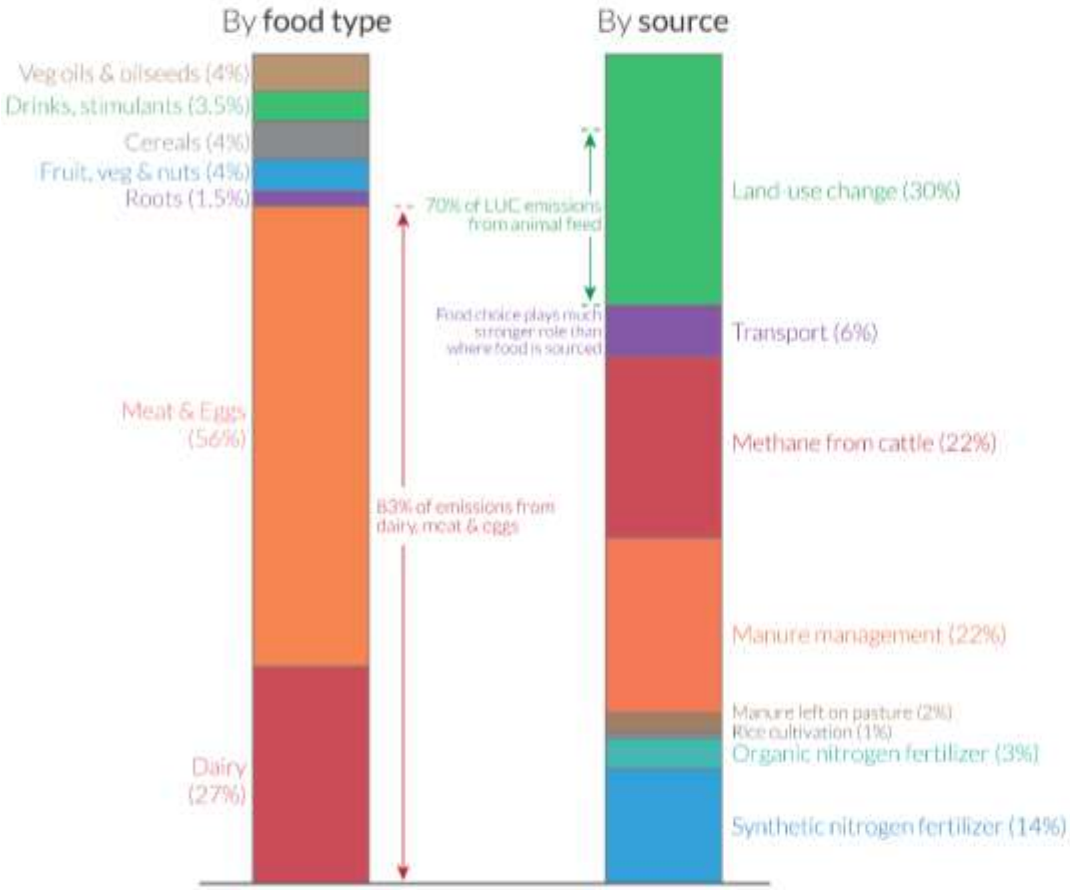

Figure 2.4: carbon footprint diets across the European Union by food type and source (Our World in Data, 2018)

In European diets, protein-rich foods account for the bulk of the dietary emissions. Meat, dairy and eggs account for 83%, as shown in figure 2.4, so as consumers, what we choose to eat has the largest impact, making a bigger difference than how far our food has travelled (with the only exception of air travel), or how much packaging it is wrapped in. Regardless of whether you compare the footprint of foods in terms of their weight, protein content, or calories, the overall conclusion is the same and is that plant-based foods tend to have a much lower carbon footprint than meat and dairy in many cases, no matter how they are produced, so the biggest difference that can be made is to change the diet and switch to more plant-based sources of protein rather than animal-based.

This can also apply to the differences between meat products. If we still want to eat meat, chicken, eggs, and pork have generally a lower footprint than beef, dairy, and lamb, so, for this reason, switching red meat with white meat is also likely to reduce the individual carbon footprint.

CHAPTER 3

Cow's milk and poultry meat production

3.1 Cow's milk and dairy production

Globally, the most productive countries regarding cow's milk production are India, with 187,96 million tonnes in 2018; followed by the USA (98,72 million tonnes), Brazil and China (34,11 and 35,6 million tonnes each). Milk production has increased through increased milk yields and improved production efficiency, the reduction in the number of small dairy farms, and the expansion of the dairy herd size. Also, increasing demand for dairy products in emerging economies has led to an increase in the global dairy trade (Bórawski et al., 2020).

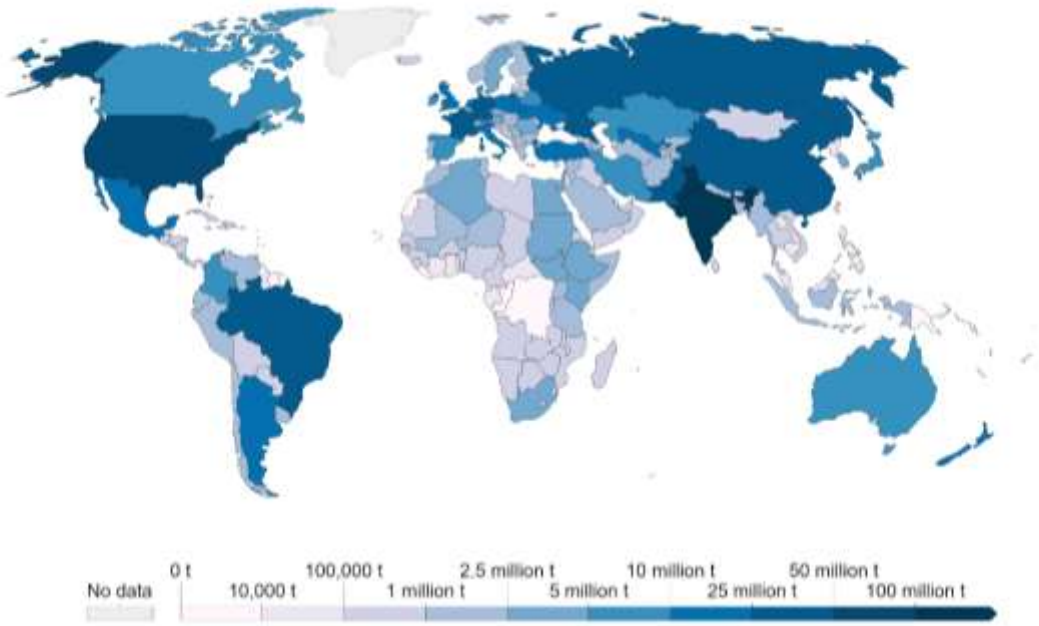

Figure 3.1: Global milk production in 2018 (Our World in Data)

The global milk market is constantly evolving, but in the last decade, there is one important element that drive the changes in the dairy market, and it is the consumer’s choice, whose preferences for milk and processed dairy products are transitioning to soybean and nut-based options as an alternative to cow’s milk (Gulseven & Wohlgenant, 2017).

3.2 Dairy cows’ lifecycle

The dairy cows’ lifecycle is different from meat cows. In order to produce milk, cows must calve, and get pregnant again to continue the production, since the lactation cycle is in the period between one calving and the next.

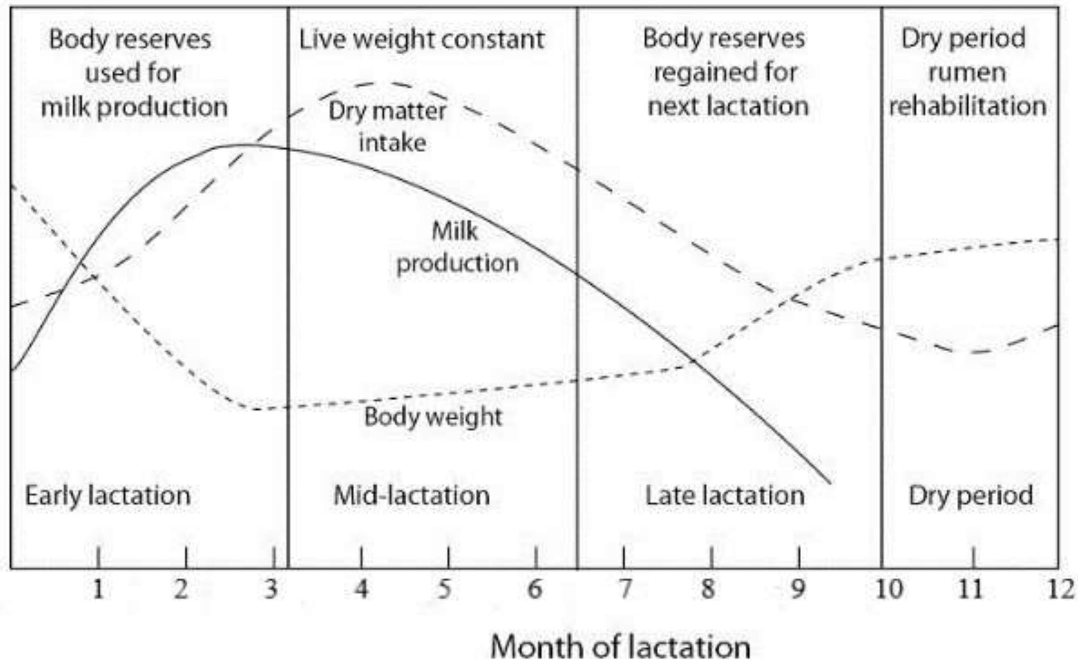

Figure 3.2: Lactation cycle of a dairy cow

The lactation cycle lasts about 305 days and can be split into four phases, as shown in figure 3.2.

The early lactation is the first phase, which lasts about 120 days. In the first 10 days, the cow produces colostrum, which is fed to the calf since it has a high quantity of antibodies, and after that milk is produced in big quantities, reaching the peak of production about 6 weeks after giving birth. The milk yield at the peak of lactation sets up the potential milk production for the rest of the year; just one extra kg per day at the peak can produce an extra 200 kg/cow over the entire lactation period. Lactating cows are milked twice or sometimes three times a day and this job is carried out by automatic milking systems, robotic milkers in which the cows go voluntarily, as it becomes a habit for them, since they feel relief after milking. In fact, an increase in productivity and, consequently, profitability is observed through improved labour efficiency using these robotic machines (Bórawski et al., 2020).

During this first phase, the cow loses weight, since most of the nutrients obtained with feeding are directed to milk production. Another reason behind the weight loss is that during the dry period, right before calving, the appetite is much lower than usual, and it takes time to get back to normal.

The mid-lactation phase also lasts about 120 days, the milk yield starts to reduce by 8-10% every month. Following the peak of lactation, the cow's appetite gradually increases until it reaches the maximum intake, but overall, cows tend to maintain weight during this stage of their lactation (Moran, 2012).

The late lactation is the last phase of active milk production for the cow, where the milk productivity reaches the minimum and it stops. Although energy and nutrients required for milk production are less demanding during this period, food is still important because of the need to build up an energy reserve for the next lactation cycle. For this reason, the cow starts to gain weight, in order to get ready for the incoming calving.

The dry period should last about 65 days. In this stage, the milk production stops completely, and all of the cows in the herd at this stage of pregnancy are forced to dry if they did not by themselves. Maintaining or increasing body weight during this period is the key to ensuring that cows have enough reserves for early lactation. If the cow calves in poor body reserves milk production suffers in early lactation because there is no stock available to contribute to energy intake, and high feeding levels in early lactation cannot overcome poor body condition at calving. Therefore, all of the energy intakes must be directed to the calf or to body storage. Depending on the breed, a newborn dairy calf's average weight is between 18 kg and 40 kg and according to the sex, it can be sold to a meat-line production or kept for the heifer replacement (Moran, 2012).

Heifer replacement is necessary to keep the herd stable in number, and the productivity level high. A heifer is ready to calve for the first time when is about 20-22 months old, and to withstand the pregnancy should be at 55% of its mature body weight at breeding. Normally, a heifer stays in the herd up until the 5-6th parturition, after which its milky production is no longer sufficient, and it is removed from the herd (Moran, 2012).

Between 3 weeks prior to calving and 3 weeks after the cow is in the transitional stage, a period that includes late pregnancy, with a rapidly growing calf, giving birth and starting to produce milk again, after several months of non-productivity. This is the most stressful and important stage in a cow's life and for this reason, they are moved away from the milking herd to a different part of the farm in which they can rest and prepare for the upcoming calving.

3.3 Dairy products

Milk is an unstable product which requires to be handled at an appropriate low temperature (up to 4°C), transported as quickly as possible, and processed within 24 hours since, over time, the count of bacteria increases, and milk metabolism intensifies. Hence, to avoid milk waste, the most common practice is to process it into dairy products, which have a longer shelf-life and fewer difficulties to store.

Milk and dairy products are significant sources of protein, essential minerals such as calcium, potassium, magnesium, phosphorous, sodium, iodine, and several vitamins, (A, D, E, K, and B1, B3, B6, B12). In the European diet, dairy products provide between 40 and 70% of the recommended daily calcium intake. Cow's milk consists of about 87% water and 12–13% total solids. The solids content is about 4% fat and 9% of solids-not-fat, such as proteins, carbohydrates, and various minerals and vitamins. Proteins are responsible for all the modification that occurs to dairy products. (Burke et al., 2018).

Dairy products are nutrient-dense foods in the overall human diet and contain most of the nutrients found in milk. Also, milk and dairy products may reduce the risk of osteoporosis and cardiovascular diseases and type 2 diabetes (Bórawski et al., 2020).

The dairy sector is also very important for the economy of the European Union and is undergoing major structural changes in the EU, the USA, New Zealand, and many other countries in the world. These changes include geographical shifts and production intensification. Dairy farmers need to invest to keep their farms in good condition, in order to maintain competitiveness in the market. Farmers should increase the rate of technology adoption to improve labour productivity because investments in dairy barns usually lead to an increase in capacity compared to the pre-investment situation and therefore allow dairy herds to grow. Furthermore, investments enable the implementation of new technologies and involve benefits associated with an increase in efficiency, a reduction in costs, an improvement in the quality of products and a reduction in the adverse impact on the environment, and improvements in animal welfare. Of course, this process requires capital (Kramer et al., 2019), but if the farmer is willing to invest, the profit will outcome the expenses.

Another important aspect to take into consideration for milk production is the decreased fertility of cows resulting from rising production and larger numbers of animals in the herd. New production technologies, including advances in genetics, nutrition, and herd management, are needed to boost dairy farm profitability (Stelwagen et al., 2013).

3.4 Poultry meat chain

Animal husbandry has undergone radical changes throughout Europe in recent decades, with fewer holdings and a concentration of production in a few specialised units, with consequent abandonment of traditional extensive practices in favour of intensive ones. This phenomenon has led to the marginalization of less favourable areas and the depopulation of mountain areas. Another consequence of the intensification of agrozootechnical practices is the increasing geographical separation between the areas of nutrient production and the areas of use where the farms are located. The concentrates used in intensive farms can be produced even hundreds of kilometres away from the company headquarters and thus cause a surplus of nutrients in the area around the farm and a depletion of organic matter and nutrients in the area of production, specifically for the Italian poultry chain (Pulina et al., 2011).

If the increased demand for products of animal origin cannot be supported simply by enlarging the cultivated areas, is not even possible to satisfy this demand with the improvement of the productivity of pastureland and more generally of fodder, as the growth margins of these crops are very limited since they already have been increased almost to the maximum. Areas intended for grazing worldwide are estimated at 3,4 billion ha and represent the main, if not the exclusive, power source in many farming systems. The conversion of the best surfaces from grazing on arable land or the implementation of agronomic practices aimed at improving the productivity of pastures do not seem to have many margins. Overexploitation of pastures with excessively high loads in arid or semi-arid areas entails, in fact, a higher risk of desertification.

The poultry sector is the fastest-growing livestock sector as a result of the global dietary demand for healthy high-protein and low-fat type of meat (Baltic & Boskovic, 2019). Globally, poultry is the most consumed meat after pork (13,8 compared to 15,3 kg/capita/year, respectively) (FAO 2015). Poultry meat is recognized as the primary driver of the growth in total meat production, in response to expanding global demand for this more affordable animal protein compared to red meats. Low production costs and lower product prices are the main triggers for making poultry becoming the most favourable meat for both producers and consumers in developing countries (Baltic & Boskovic, 2019).

The meat industry has seen major improvements in the genetics, health, husbandry, and processing segments. Especially in the poultry sector, growing broiler breeds selected for a faster growth rate led to a significant markup in average yield and productivity. In 1925 it usually took 112 days to grow a broiler to a market weight of 1,2 kg, while in 2010 it took only 47 days to get to a weight of 2,5 kg (Barbut, 2015). It should be noted that livestock farming has also changed a lot during the last century since in the 1920s chickens were grown in small backyards and the same breed was used for both egg and meat production. When the industry started to grow and specialize, different egg and meat production breeds emerged, and farmers began to specialize in one or the other. Genetic selection for more efficient meat-producing breeds has also resulted in improved feed efficiency, meaning that the kilograms of feed required to produce 1 kg of meat gain were reduced, improving the conversion rate from 2,13 kg to 0,87 kg in some of the highest yield breeding.

These improvements along with innovation/modernization in the primary processing sector and in agriculture in general (e.g., growing more corn or soy per acre) have resulted in consumers paying less today for poultry meat than they did 25 years ago (Barbut, 2015).

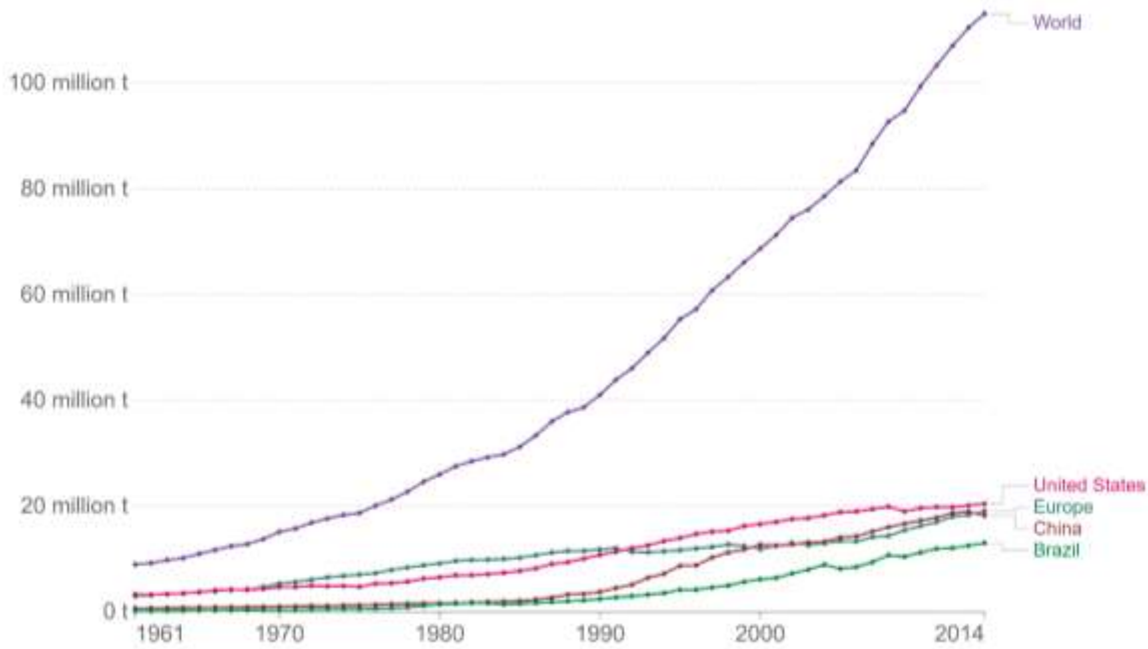

Figure 3.3: Poultry production from 1961 to 2014 (Our World in Data)

From the graph shown in figure 3.3, it is clear that the global production of poultry meat has grown more than twelve times between 1961 and 2014. Still, the United States is the world's largest producer, with more than 20 million tonnes in 2014. China and Brazil are also large poultry producers with 18 and 13 million tonnes respectively. Collectively, Europe is also a major poultry producer with an output in 2014 of approximately 19 million tonnes, just below the United States.

A concept that is being more and more implemented in the commercial chicken industry is the so-called “vertical integration”, which means that a firm can extend its influence by taking over key steps in the whole supply chain. In fact, vertical integration refers to single companies owning feed mills, hatcheries, breeder farms or rearing of laying hens, and processing plants. Arrangements typically involve agreements in which the farmer or landowner provides the housing, equipment, and labour, while the company provides the chicks, feed, medication, transport, and supervision (FAO, 2013). The deep integration of animal husbandry in the whole agri-food sector through multiple and continuous exchanges of raw materials and resources makes both agricultural and livestock systems more efficient and sustainable from an economical point of view.
Several benefits derive from this unification starting with access to more management information, free communication, and cooperation throughout the different stages of the supply chain. Furthermore, continuity of supply can guarantee more product customisation possibilities, and direct influence over manufacturing factors such as quality, delivery, and cost, while welfare, health, and hygiene protocols can be implemented more effectively through the supply chain (Manning & Baines, 2004). This integration into cooperatives or small/large industries permits the small farmers to optimise costs and to access advanced technological systems that allow the increase in productive efficiency, with a consequent saving of resources and reduction of the environmental impact while reducing the risk of abandonment of the countryside.

3.5 Broiler livestock

Poultry farming starts from the moment the chicks are brought to the growth sheds. For broilers, there are three different commercial categories:

- *Light chicken*: destined to be sold whole. Usually, they are females slaughtered at less than 36 days, with a live weight of about 1,5 kg.
- *Average chicken*: usually females (maximum limit, past this limit they no longer grow in meat but get fat) and part of the males, slaughtered at 42-48 days of life with a live weight of about 2.5 kg. This is the size suitable to originate minimally processed products, usually cut into parts (chest, thigh...)
- *Heavy chicken*: only males can be slaughtered at more than 50 days of age because they can increase muscle, while females would be too fat. They have a live weight of about 3-4 kg and are suitable for all processed products.

Modern barns commonly house 20,000 to 30,000 broilers per cycle of production, depending on the size of the bird and the stocking density. Broilers are usually marketed at 6 to 8 weeks (about 49 days) and collected all together at the same time. After the barn is emptied, it starts the cleaning cycle and a period where no livestock is kept in the shed which lasts from 14 to 21 days. This is an action made to prevent the spreading of poultry diseases and to ensure the hygienic conditions for the new livestock cycle.

Most poultry is raised on a litter made of wood shavings or other plant materials, and the barn is equipped with watering and feeding devices that are commonly suspended from the ceiling (Barbut, 2015).

Chickens have seasonal and daily biological rhythms, both of which are mediated by light, particularly day length. For day length to exert its controlling effect, there needs to be a dark phase (night) when light levels should be less than 0.5 lux (FAO, 2013). The effects of light are predominantly on the rate of sexual maturation and egg production but are also very important for the animal’s health since chickens are quite creatures of habit.

The most important aspect of broiler chick management is creating an environment without temperature fluctuations. Light sources are needed along the brooding area above the heat source in the house, to attract chicks to the feed and water. These lights should be used during the first five days after the chicks arrive, after which background lights should be gradually increased, to reach normal lighting by the tenth day. A well-insulated roof reduces solar heat penetration into the house on warm days, thus decreasing the heat load on the birds, and reduces heat loss on colder days. This way, it also lowers the energy consumption needed to maintain the correct environment for broiler chicks during the brooding phase.

It is essential that meat birds have adequate room, whether they are housed in small groups on village farms or in larger semi-commercial or commercial sheds. Lack of space can lead to leg problems, injuries, and increased mortality (FAO, 2013). As they approach market weight, an approximate maximum stocking density for fully confined birds on deep litter is 30 kg of bird per square metre of floor area.

CHAPTER 4
Response-Inducing Sustainability Evaluation (RISE) software

4.1 What is RISE

The purely economic competition that led to environmental and social dumping is being transformed into a more multi-dimensional competition where an agricultural enterprise's success is measured by its profitability and its accomplishment of social and environmental goals. While there is still demand for innovations that boost productivity and resource efficiency, a growth that harms the health of humankind and nature is no longer considered acceptable. Since the most severe and long-lasting environmental impact is at the farm stage, the Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences developed a software called RISE - Response-Inducing Sustainability Evaluation.

The Response-Inducing Sustainability Evaluation (RISE) is an indicator-based methodology for the holistic assessment of agricultural production at the farm level. The goal of RISE is to contribute to the dissemination and consolidation of the philosophy and practice of sustainable production. The target group of RISE comprises all the stakeholders in agriculture, society and business who share this vision, and the use of RISE makes it easier to measure, understand and implement the vision of sustainable development since the software quantifies and evaluates the farm's contribution to sustainable development, as well as the extent to which its production system complies with the principle of sustainability.

Drafted in 1999, the first version of RISE was born to asset sustainability in agriculture in an international way, this evaluation is achieved by comparing data collected on all the farm's spheres of activity against benchmarks derived from the definition of sustainability.

To develop the software, the authors started with the interpretation of sustainable development from three perspectives:

- *Anthropocentric*: "Sustainable development is an anthropocentric concept centred on meeting the needs of present and future generations" (Jörissen et al., 1999). The term "needs" primarily refers to basic needs and once these needs have been met, everybody should have the opportunity to satisfy their desire for a better life.
- *Dynamic*: rather than simply preserving certain goods and balances, to make the most of development potential it is also necessary to make sure that alternative strategies are in place (Luks, 2002).
- *Holistic*: While the sustainable development paradigm includes the economic, social and environmental dimensions, RISE is based on a holistic understanding of sustainability in which no separate dimensions are distinguished.

4.2 RISE ideal farm

The farm produces food, feed and other agricultural products and services in line with public and trade demand and in keeping with its potential as determined by the local climate, soils, and socio-economic conditions. It creates and maintains an environmental, economic, and social buffering capacity and maintains or increases the productivity of its natural, financial, and human capital. Non-renewable resources are only used if a physically and functionally equivalent renewable replacement can be made available and demand for non-renewables can be reduced through higher efficiency and lower resource intensity. The indirect use of non-renewable resources is steadily reduced. Soil and water use should not exceed their regeneration rate or irreversibly compromise their quality as a resource and habitat. The farm management employs knowledge and technology to improve resource efficiency. Production inputs are used as extensively as possible and only as intensively as necessary. The farm's production system helps to protect and promote the diversity and functionality of its ecosystems. No harmful substances are released into the soil, water or atmosphere in quantities that exceed their carrying capacity and resilience or that could pose a threat to human health. Indirect pollutant emissions are steadily reduced. Livestock is kept in conditions that promote their health, meet their physiological requirements and, as far as possible, allow them to behave in a breed- and species-appropriate manner.

The people working on the farm are provided with decent and healthy working conditions that respect their human rights. This includes fair wages and treatment regardless of gender, age, religion, nationality, skin complexion or personal convictions. As long as they comply with the relevant safety and sustainability requirements, all people working on the farm are free to choose how they live and work. The farm environment provides everyone who works there with access to resources, education, and participation in economic and social life. The wages allow the people on the farm and their families to enjoy a standard of living that guarantees their mental and physical health and well-being, including food, water, clothing, healthcare, and essential social services. The farm yields a revenue that allows the owner to pay their debts on time and invest in replacement or new sustainable production and farm management systems. The farm is buffered against natural and socio-economic turbulence. Its survival does not depend on single suppliers, customers, products, or government subsidies. The farm and its people are protected through a network of formal and informal mechanisms (Grenz et al., 2018).

4.3 Themes and indicators

The RISE indicator set is based on a model defined on social, economic and environmental basis. To meet the needs of the people on the farm, the farm uses human, financial, and natural resources to produce goods and services, as well as emissions and waste. The most important quality criteria for selecting the RISE topics and indicators are theoretical and practical relevance, cost-benefit ratio, methodological soundness and transparency.

Version 3.0 of RISE has a flexible indicator set, in order to better reflect the diversity of production conditions in the agricultural sector and the different requirements of its users. Although the 10 RISE themes are fixed and all of them must be included in the analysis, the level of detail can be varied. The flexible configuration of the indicator set is initially carried out at the project level, where the project administrator can enable different topic options for each of the ten RISE themes. A topic option contains a set of carefully aligned indicators that can also have different algorithm options. The list of themes and indicators is shown in table 4.1.

Topics	**Indicators**
Soil use	• Soil management • Crop productivity • Soil organic matter • Soil reaction • Soil erosion • Soil compaction
Animal husbandry	• Herd management • Livestock productivity • Opportunity for species-appropriate behaviour • Living conditions • Animal health
Material use & environmental protection	• Material flows • Fertilization • Plant protection • Air pollution • Soil and water pollution
Water use	• Water management • Water supply • Water use intensity • Irrigation

Energy & Climate	• Energy management • Energy intensity • Greenhouse gas balance
Biodiversity	• Biodiversity management • Ecological infrastructures • Intensity of agricultural production • Distribution of ecological infrastructures • Diversity of agricultural production
Working conditions	• Personnel management • Working hours • Safety at work • Wage and income level
Quality of life	• Occupation and training • Financial situation • Social relations • Personal freedom and values • Health
Economic viability	• Liquidity • Stability • Profitability • Indebtedness • Livelihood security
Farm management	• Business goals, strategy and implementation • Availability of information • Risk management • Sustainable relationships

Table 4.1: RISE theme & indicators complete list

The farm data is compared against the benchmark data and normalized to a scale from 0 to 100 using a scoring function. 100 points represent an optimal result, a completely sustainable way of doing things, whereas 0 represents an unacceptable situation. In some instances, it is necessary to combine farm data and standard data. The scores resulting from the normalization to this scale are referred to as indicator scores. A theme score is calculated using the arithmetic mean of several indicator scores, with all indicators being given equal weighting. The collected data are partially adapted to regional conditions, which are chosen at the beginning of a project. An interactive questionnaire is used for the benchmark values and weightings that can be influenced by the stakeholders themselves, thus responding to the demand for stakeholder involvement. This serves to mitigate the conflict between global applicability on the one hand and relevance to individual farms on the other.

All evaluated data are given a colour code: red indicates a problematic area, yellow means that further attention is recommended and green indicates good performance (Figure 4.1).

Degree of sustainability	Problematic 0 – 33	Critical 34 – 66	Positive 67 - 100

Figure 4.1: Scores and colour codes used in RISE

The highest aggregation level for RISE results is the sustainability polygon, which shows the degree of sustainability for all the different topics at a glance (Figure 4.2).

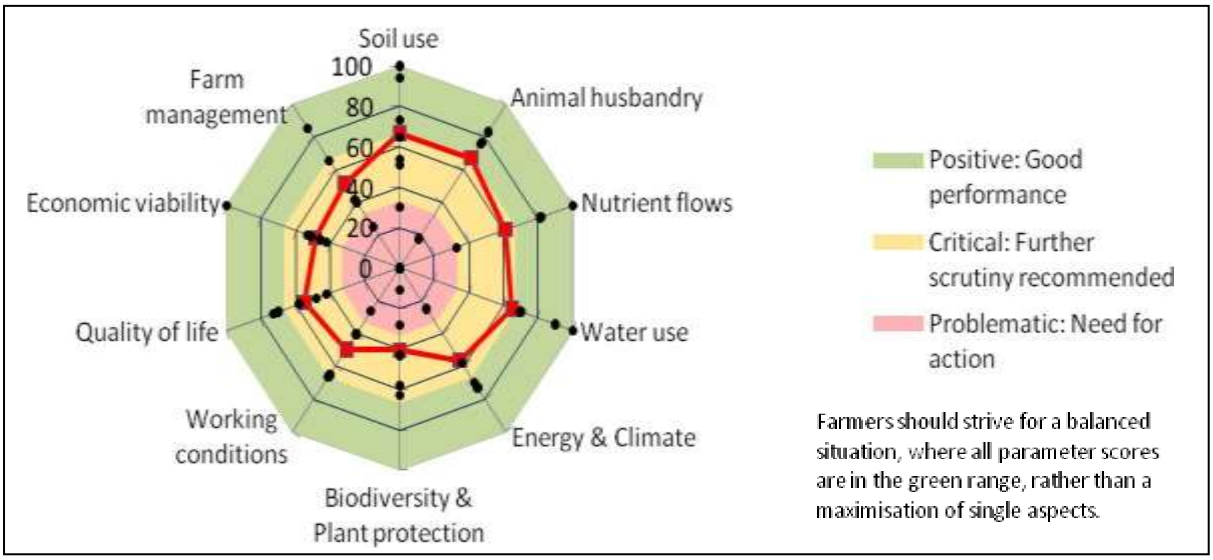

Figure 4.2: Example of the sustainability polygon

4.4 RISE themes

4.4.1 Soil use

Fertile soils are a limited, easily degradable resource essential to both life and production. Humans use soil to grow food and fodder crops and renewable raw materials; to build on; but also, soil can purify water, give us raw materials to use; store carbon and acts as an archive of natural history (BMU, 2002). In ecosystems, it plays an indispensable role as a buffer, filter, and habitat. Fertile soil provides plant roots with stable anchorage and a balanced supply of water, heat, air, and nutrients, whilst at the same time preventing toxic accumulations of growth-inhibiting substances.

Soil fertility is determined by the quantity and quality of soil organic matter and clay minerals, texture and structure, soil pH and depth (Craswell & Lefroy, 2001). While its quantity is hard to increase, fertile soil can be easily destroyed. In the majority of the global agricultural area, problematic soils restrict plant growth (FAO, 2017) and although soil texture and clay mineral content are difficult to change in the short term, soil organic matter content can be modified within certain limits. Land use can have a more rapid impact on soil depth, structure, pH, nutrient content and pollutant content, and to some extent also on the quantity, diversity and activity of soil life.

The most important soil degradation processes that affect the surface area and have more impact are water and wind erosion, salinization, compaction and pollution. Soil sealing, soil organic matter loss, acidification, over-compaction and the formation of salt or metal oxide crusts are also problematic in some regions. Soil degradation causes problems off-site as well, including sedimentation and eutrophication of canals and water bodies, dust emissions, flooding and emissions of greenhouse gases (MEA, 2005).

The indicators included in this topic are aimed to examine the farmer's practices but also to determine how much the surrounding environmental impact affects the soil.

4.4.2 Animal Husbandry

Animal husbandry is an integral part of many agricultural production systems. Livestock should be kept in a manner that ensures their welfare and does not harm the environment. Animal welfare-friendly practices encompass the “five freedoms”: freedom from hunger or thirst, freedom from discomfort, freedom from pain, injury or disease, freedom to express normal behaviour, and freedom from fear and distress (FAWC, 1979). At the same time, high performance and resource efficiency should also be pursued.

Livestock production also has considerable economic significance, and since the intensification and spread of livestock farming have been occurring in more and more parts of the world in recent decades, it has been the subject of criticism due to its environmental impact. Indeed, about 20% of all pasturelands are affected by soil degradation (Steinfeld et al., 2006) and, particularly in the tropics, large tracts of land are being deforested in order to create new pastureland. Also, long-distance transportation of animal feed causes nutrient excesses in the importing regions and soil degradation in the exporting regions (Grenz et al., 2018), but the biggest impact is given by the greenhouse gas emissions, as livestock production is a major source of man-made ammonia and methane emissions.

Another important aspect of livestock is the feeding that is necessary to feed all the animals. Close to one-third of global arable land is used to grow animal feed (Steinfeld et al., 2006) and since the bulk of the energy contained in the crops is lost during their conversion into meat, these areas contribute less to global food security than they would if they were used, for example, to grow cereals for making bread. Moreover, the use of antibiotics, hormones, painkillers, anaesthetics and antiparasitic drugs has the potential to harm the environment given that up to 90% of all antibiotics used in livestock fattening are excreted in urine and manure where they can find their way into the soil and water. Some antibiotics are toxic to aquatic organisms, soil organisms and plants, although the concentrations measured to date are not considered likely to cause acute environmental problems. Of far greater concern is the evolution of antibiotic-resistant pathogens (Boxall et al., 2003).

In spite of the threats that it poses to the environment, livestock production plays an important role in sustainable agriculture as long as stocking densities are adapted to farm size, nutrients are kept in tight cycles and housing, and feeding and breeding take animal welfare into account. As sentient creatures, animals are protected by law in many countries. For both ethical and agronomic reasons, they should be kept in a manner that ensures their well-being and their natural needs. In order to ensure their usability in the field, it is important to draw a precise distinction between the concepts of enabling species-appropriate behaviour on the one hand and keeping animals in welfare-friendly conditions on the other. Species-appropriate systems are those where the animals can live as they would in the wild. Welfare-friendly systems are those that meet the animals' needs as domesticated animals that have been bred like livestock. Even a species-appropriate livestock production system may come into conflict with other aspects of sustainability. For example, ensuring continuous availability of water can increase water consumption, free-ranging animals produce higher ammonia emissions and welfare-friendly livestock production systems often involve increased workloads and costs. Nevertheless, resource use, workload and costs should not be minimized at the expense of animal welfare (Grenz et al., 2018)

It is not possible to measure animal welfare directly, nor can it be extrapolated solely from animal performance and health. The animal condition can be captured based on pathological symptoms and zootechnical interventions such as docking, polling and castration. Husbandry systems can be assessed on the basis of livestock performance, housing (light, space, temperature, etc.), feeding and herd management. RISE's scoring system for animal husbandry is based on information provided by the farmer, as well as a brief tour of the animal housing facilities and pastures. It focuses on easily recordable indicators such as lighting and air quality in animal housing and livestock mortality and performance, also according to the EU laws in force.

Sustainable livestock production requires livestock farmers to be well informed about their animals' health and performance. Customers and government authorities are increasingly demanding detailed documentation in order to prevent outbreaks of animal epidemics and zoonotic diseases and to ensure product traceability.

4.4.3 Material use & environmental protection

Sustainable agricultural production makes use of natural nutrient cycles because it preserves a good nutrient balance even at high productivity levels while minimizing environmental pollution and materials use. This topic provides an indication of whether tight cycles and sustainable origins are taken into account by materials sourcing (fertilizer, feed, etc.) and whether damage to the environment is avoided in the storage, use and disposal of materials.

Nowadays, many farms use large quantities of a wide range of materials, and it is very difficult that agricultural production still occurs without the use of external inputs. Unless these materials are used in a targeted and sparing manner, their environmental impacts can be significant. Nutrients that escape into the atmosphere can cause eutrophication of rivers and soil. Plant protection products pose a threat to life forms throughout the environment, while waste products can also cause contamination of soil, water bodies and the air and poison the creatures that live there. The materials used on farms can also endanger the health of the people who make and use them.

This topic takes into account the use of fertilizers, plant protectors, the material flow and the potential soil, water and air pollution derived from the technologies applied. Fertilizers affect sustainability mostly because they contain Nitrogen and Phosphorous, two chemical elements that are the most frequently associated with reduced yields and also have the greatest impact on the environment. Therefore, they are key drivers of both agricultural productivity and the environmental impact of farming. Nitrate, ammonia and nitrous oxide are highly mobile, crops can only absorb 50% or less of the applied N (Crews & Peoples, 2004). As a result, nitrogen flows from vegetation and soil into open water and groundwater have more than doubled as a result of human activity.

Phosphorous is an element that is mainly made available for agricultural use through open-pit mining. Phosphate rock is a non-renewable resource, meaning that global stocks are limited, therefore, ways of using it more efficiently and recycling it more effectively are the subject of intensive research efforts.

Agriculture also suffers huge losses due to wild plants, wild animals and pathogens that eat, attack or compete with crops and livestock. Plant protection products (PPPs) are more and more implemented in agricultural practices, especially in the most extensive ones. Inappropriate use of PPPs can cause them to accumulate in the soil, water bodies and into the products damaging the health of humans and ecosystems. In addition to the danger of acute poisoning, there is also a risk of chronic diseases and genetic damage, especially among people handling PPPs (McCauley et al., 2006), not to mention the evolution of PPPs resistance in the agricultural crops.

It is always to keep in mind that farms produce large quantities of waste, ranging from recyclable materials such as manure, harvest residues, glass and metal to problematic waste such as chemical containers and waste oil. Inappropriate waste management can endanger human, animal and environmental health. Legacy contamination can also harm future generations and therefore clearly violates the principle of sustainability. Waste management should follow the principles of the circular economy: first and foremost, waste should be avoided by minimizing its quantity and hazardousness; second, any waste that is produced should be recycled (including composting) or used as a source of energy. If the waste cannot be avoided or recycled, it should be disposed of in an environmentally friendly manner.

4.4.4 Water use

Clean fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment (GWP, 2000). It is indispensable both for human life, and for crop and livestock production and the production system employed by the farmer affects the amount and quality of the water available to other users. This topic addresses how good the quality and quantity of the farm's water supply are, how intensively and efficiently water is used for production and how sustainable the farm's irrigation practices are.

Of the 4 trillion m^3 of freshwater used by humans every year, nearly 70% is used in agriculture (FAO, 2017). While water is often reused several times, its quality usually deteriorates as a result (IWMI, 2006). Contamination with toxic chemicals or faecal germs and inadequate water treatment can also cause more immediate harm to human and animal health, both on farms and in their vicinity. Over the longer term, quality problems may arise from the accumulation of toxic substances in the soil and in water pipes, as well as the contamination of water with chronically toxic chemicals.

4.4.5 Energy and climate

In order to be fully sustainable, agricultural production must be energy-efficient and not reliant on non-renewable, environmentally harmful energy carriers. This helps to protect the climate, which in turn has an impact on plants, humans and animals' health. This topic addresses the extent to which production on the farm is reliant on non-sustainable energy sources, which energy-saving measures have been implemented and the net volume of greenhouse gases emitted by the farm.

One peculiarity of the primary sector is that it can produce more energy than it consumes. Prior to the age of fossil fuels, energy availability was determined by the area and productivity of vegetation (Grenz et al., 2018). The advent of fossil fuels made more energy-intensive practices feasible thanks to their high energy density and low price. Improvements in farm energy sustainability can be achieved by reducing energy consumption and using energy from renewable sources. Particularly energy-intensive processes include heating of buildings, milk cooling, barn ventilation, hay drying using fuel oil, feed distribution, tillage, irrigation and greenhouse heating. Farms can also produce energy in the form of biogas, firewood, agro-fuels, solar power (electricity or heat) and wind and waterpower (Dore, 2005).

Weather and climate conditions within the ecological tolerance of the regional flora and fauna are essential for the productivity and stability of natural and agricultural ecosystems. Weather records, data obtained from ice cores and sediments, observations of plant phenology and other evidence all indicate that the climate is warming in nearly every part of the globe and increases in emissions and atmospheric concentrations of greenhouse gases have also been documented. Further increases in atmospheric GHG concentrations are expected in the future and rainfall is forecast to become more variable overall (Dore, 2005). The predicted impacts of climate change on agriculture include yield gains at higher latitudes and losses at lower latitudes, more severe pest damage and increased soil erosion caused by torrential rain (Smith et al., 2007). The frequency of storms, heatwaves, flooding and landslides is forecast to rise, while the incidence of lightning increases exponentially in relation to rises in mean monthly temperature.

Methane emissions from livestock production, nitrous oxide and carbon dioxide released from arable land and carbon dioxide emissions from the burning of fossil fuels also contribute to climate change.

Energy plays an extremely important role in farming. There is actually no shortage of energy on the Earth’s surface and its use in farming is not necessarily harmful to the environment. However, since the main energy sources currently used in agriculture are diesel and electricity, mostly derived from fossil fuels, agricultural energy use is not presently sustainable. the RISE scoring system penalizes very high energy intensities even if only renewable energy is used since the production of energy places high demands on land and resources and causes damage to ecosystems. The goal should be both to reduce energy intensity and to completely abandon the use of non-renewable energy sources (IPCC, 2013).

4.4.6 Biodiversity

Biodiversity is the diversity of ecosystems on Earth, the diversity of the species in these ecosystems and the diversity of the genome within these. The functioning of ecosystems and their ability to provide us with what we need to live is closely linked to biodiversity (Balvanera et al., 2006). The diversity of living organisms and the health of ecosystems are tightly connected. This topic addresses what is being done to promote the diversity of species, varieties and breeds on the farm, how well natural ecosystems are preserved and connected within the agricultural landscape, the quality of plant protection management and whether substances that are toxic to humans and nature are used for crop and livestock protection. In recent decades, humans have profoundly altered the world's ecosystems across large parts of the world. More and more areas of natural ecosystems are being transformed into agricultural land. Intensive fertilization, plant protection and tillage create homogenous, eutrophic conditions across large areas. The consequences include species loss and damage to ecosystem services (MEA, 2005).

Agriculture is a custodian of both wild and agricultural biodiversity in and around the areas it manages. It has several powerful means of influencing biodiversity at its disposal: allocation of land to different uses, crop rotation design, selection of species, varieties and breeds, and choice of farming practices.

RISE assesses biodiversity indirectly based on the diversity of the wild and farmed plant and animal species on the farm and the ecological quality of the landscape. Indirect indicators include the percentage of land that is ecologically valuable or important to local culture (stands of trees and bushes, hedgerows, uncultivated field margins, etc.), participation in agri-environment schemes, number of crop species and varieties and livestock breeds, mixed cropping, conservation of regional varieties and breeds. The RISE analysis records and assesses the land used by the farm separately according to its type and use.

4.4.7 Working conditions

A committed and productive labour force is a basic requirement for a successful farm. Both of these traits are strongly influenced by on-farm working conditions. This indicator assesses the objective working conditions for farm employees and self-employed farm labour.

Since poor working conditions result in employees having to take time off work, dissatisfaction and reduced productivity, they are directly linked to economic success. Specifically, long working hours increase the risk of accidents, contact with chemicals and pesticides can lead to acute or chronic diseases and the inhalation of dust can cause lung damage (Thaon et al., 2006).

Work-related accidents and diseases result in high economic costs that affect both regional and national development. In addition to economic arguments, there are also ethical reasons why good working conditions are indispensable to sustainable development. A variety of national and international regulations set out standards for healthy and humane working conditions (UN human rights, ILO, SUVA Guidelines, EU federal laws, etc.), especially in agriculture, where far more people report long working hours than in any other sector (EWCS, 2007).

Working conditions are affected by a variety of factors, grouped into four areas:

- Physical work factors (e.g. how physically demanding the work is, exposure to chemicals)
- Work organization (e.g. type of work, working time)
- Social and psychosocial environment (e.g. high work intensity, time pressure, lack of support, monotonous activities)
- Human resource management factors (e.g. ongoing training, appropriate allocation of work, remuneration)

This topic focuses on the objectively measurable properties of the workplace, while the subjective evaluation of working conditions (job satisfaction and motivation) is covered under the “Quality of Life” topic. The results of both topics should be considered together to have an overall picture. Wherever possible, data should be collected for everyone working on the farm.

4.4.8 Quality of life

Quality of life is the physical, mental and social well-being of an individual. It involves the desire of every person to lead a life in which they are able to meet not only their basic needs but also their social, cultural and societal need. Quality of life, satisfaction and happiness are important indicators of successful sustainable development.

The quality of life experienced at any given moment is determined by a variety of factors, including interpersonal relations, social integration, personal development, physical health, self-determination, material wealth, emotional well-being, rights, environment, family and leisure (Verdugo et al., 2005). Reactions to poor quality of life include low motivation and commitment, burn-out, simmering conflicts and health problems. Several challenges arise when assessing the quality of life. First, quality of life is a cross-cutting issue and is determined by several very different aspects of a person's life; secondly, how a person evaluates their quality of life depends on their individual goals. Both the relevant areas of their life and their individual goals are shaped by their environment, culture, experience and personal preferences (Wirtz et al., 2009). RISE determines the quality of life letting the interviewees directly rate their satisfaction with the different areas of their lives and their ratings are then converted into a score of between 0 and 100.

4.4.9 Economic viability

A farm is first and foremost a business that needs to deliver economic goals whilst working within the relevant environmental and social constraints. The aim is to ensure the short and long-term profitability of the business and to maintain or even improve productivity so that the business can develop in a stable and self-determined manner that guarantees the livelihood of the farmer's family and the income of the people employed on the farm. This topic addresses the aspects of a farm's economic viability such as liquidity, stability, profitability, indebtedness, and livelihood security.

The economic dimension of sustainability is typically determined through the aspects of profitability, liquidity and stability. There are three main reasons why it is difficult to determine what a sustainable profitability level is for an agricultural business:

First, the widely pursued goal of maximizing returns requires capital to be invested in the investment that promises the highest interest and most reliable returns. This places sustainable forms of investment at a disadvantage since they usually have lower financial returns. Second, returns can only be maximized if there is sufficient capital mobility. However, the bulk of the capital in an agricultural operation is usually tied up in land, fixed assets and livestock. Third, the exact values used as the basis for calculating rates of return are often almost impossible to determine in the agricultural sector. In many countries, land prices are subject to special regulations that prevent them from being set freely (Grenz et al., 2018).

RISE, therefore, expresses economic viability primarily through liquidity and stability indicators, because RISE is designed to be as widely usable as possible.

All over the world, access to money is one of the factors that act as a constraint on sustainable socio-economic development. Farms will often use wage dumping among members of the farmer's own family so that they can continue to invest and maintain their production systems. This results in low wages and long working hours for farm employees and reduced spending power for self-employed farmworkers, which ultimately negatively impacts the farm's social sustainability. While the worldwide trend towards specialization and ever-larger production units has contributed to increased efficiency, it has also made businesses more vulnerable to market fluctuations, which are likely to become more frequent as a result of market globalization. Professional farm management is becoming increasingly important in all parts of the globe in order to ensure that opportunities and threats are identified, and the appropriate measures are taken in good time.

4.4.10 Farm management

It may be perfectly viable to run a farm using traditional methods, even over the longer term. However, changes will need to be made if a poorly designed management process coincides with manifestly unresolved challenges. Where this occurs, it is necessary to modify the farm's strategy by implementing measures that incorporate sustainability into management systems, processes and culture. In order to achieve the best sustainable farm management, the framer should have access to the knowledge needed to make informed decisions; he also should pursue goals and strategies that are in tune with the stakeholders' personal values and take into account the natural limitations of people, animals, the environment, finances and society. The farmer should regularly assess internal and external risks so that proactive measures can be taken and resources can be employed productively, safely and profitably; and at last, he should cultivate sustainable relationships, ensuring that dealings with people and stakeholders both on and off the farm are characterized by respect and fairness (Grenz et al., 2018).

The main aim of this theme is to understand how the farm is managed. The farm's sustainability and the results for the other RISE topics are heavily dependent on the approach and quality of the farm's management.

CHAPTER 5

Experimentation: RISE assessment in dairy and chicken broiler farms

5.1 Aim of the project

This master thesis aims to apply the RISE software to estimate the sustainability level of a farm giving an example and a concrete assessment of the definition of food, environmental and economic sustainability in animal husbandry and agriculture. In this experimentation, two farms were taken into consideration in two different countries, a dairy farm in Germany and a broiler chicken farm in Italy.

The first part of the project was performed in Germany, as a part of the Erasmus+ mobility for Traineeship with Hochschule Rhein-Waal - University of applied sciences in Kleve. The dairy farm was chosen considering that dairy cows are the main form of farming in that area of Germany.

The idea of applying the software to a broiler chicken farm was born to test the feasibility of the project and the eventual reliability of the results since, so far, the RISE software has only been applied on farms with cattle and sheep livestock or crop productive farms.

The dairy farm case study was developed during the three months exchange period, while the poultry farm case study was carried out in Italy, after the end of the Erasmus+ program.

5.2 Case #1: Dairy farm

The use of the RISE method contributes to sustainable agriculture by translating the sustainability paradigm to the farm level and by making sustainability measurable, communicable and tangible. By addressing sustainability deficits and potentials, the economically oriented farm management is complemented by the environmental and social dimensions. RISE is not a control method nor a certification protocol but is designed to contribute to education and consultancy schemes that aim at a knowledge-based, motivated, and sustainable development of agricultural production at the farm level.

The RISE method is transparent, in the way that purpose, process, benefits and possible consequences of participating in a study are explained to farmers prior to the start of the analysis. It is also voluntary since nobody must be forced to participate in a RISE assessment and disclose sensitive information or implement measures if they do not want to. About this, it must be said that the method is also confidential, and the information collected or generated in a RISE study will not be forwarded without consent of the concerned farmers, neither within nor outside an institution. Strict standards apply concerning privacy protection and data safety. Lastly, the RISE method is thorough since consultants and trainers must command intimate knowledge of and experience in agricultural production and sustainable agriculture.

The first step of any RISE project is the definition of goal and scope. RISE projects serve to:

- better understand the agricultural basis of value chains and create a knowledge basis for action plans in the context of sustainable sourcing strategies
- enhance the hands-on knowledge of company personnel or students about agricultural production and sustainable agriculture at the farm level
- identify entry points for agricultural development projects
- support farmers and farm managers in developing and implementing a sustainable strategy for their operations.

The sustainability analysis of an individual farm starts with contacting and informing the farmer. If he or she agrees to participate in the analysis, the interview is scheduled, which takes up to four hours since is the main source of information for the assessment, and the visit must include a short tour of the farm and fields to examine the areas. The existing farm documentation is used to the greatest extent possible.

5.2.1 Materials & Methods

The farm to which this study is related is settled in Germany, in the Lower Rhine region (Niederrhein), in North Rhine-Westphalia. It is a dairy farm led by the farmer and his family, with the help of a few employees. The farmer stated that this job was destined for him, since it is a family tradition, and his ancestors were farmers. The farm's dimension is suitable for the family size, and all the milk produced and collected is sold to other dairy companies.

Once all data have been entered and checked for plausibility, the RISE indicator and theme scores can be calculated. This is done through a sequence of calculations, partly using reference data from the RISE database, and involving normalization. All scores are converted in simple numbers, from 100, which represents an optimal (fully sustainable production), to 0, an unacceptable situation, and colour coded. Some of the RISE valuation functions are regionally adapted at the beginning of a project, for example, humid and arid climates are distinguished, and regional water scarcity is taken into account.

The results are shown with the sustainability polygon, which is a visualization of whole-farm sustainability, as well as comprehensive tables including intermediate values needed to better understand indicator and theme scores. The results must be discussed with the farmer, to also get a comparison with his/her point of view, since the theoretical solutions are not always aligned with their real applicability. If desired by the client or the farmers, the conclusions can also include recommendations of measures through which performance could be enhanced. These recommendations are discussed with experts for the respective topic to be effective.

5.2.2 Results and discussion

The results are shown in two different ways, in a table and in a visual way.

The complete list of themes displayed in table 5.1 clearly shows the problematic areas, the colour-coding is very efficient at this. Six out of ten themes are considered of good rank, whereas the other three indicators are considered to have a medium performance and only one is very low ranked.

1	Soil use	68 points
2	Animal husbandry	92 points
3	Materials use & environmental protection	75 points
4	Water use	84 points
5	Energy & Climate	35 points
6	Biodiversity	33 points
7	Working conditions	72 points
8	Quality of life	61 points
9	Economic viability	37 points
10	Farm management	78 points

Table 5.1: Themes results extracted from RISE software

The overall visual result is displayed in the sustainability polygon in figure 5.1. This points out both themes and indicators while showing the general outcome of the project. The background of the figure is divided into three main colours, red, yellow and green. The central part in red indicates the lowest score, meaning that many improvements can be made, the yellow stands for a middle-score zone while the green zone states a very good result. This visualization comprehends each theme analysed, which is shown as linear rays that go from the centre of the figure to the external part. On each ray, we could see some black dots, which embody the indicators included in the theme, and their position represents their rating. The red line that connects every theme is the mean value of each theme, which gives a visual representation of the overall degree of sustainability of the farm.

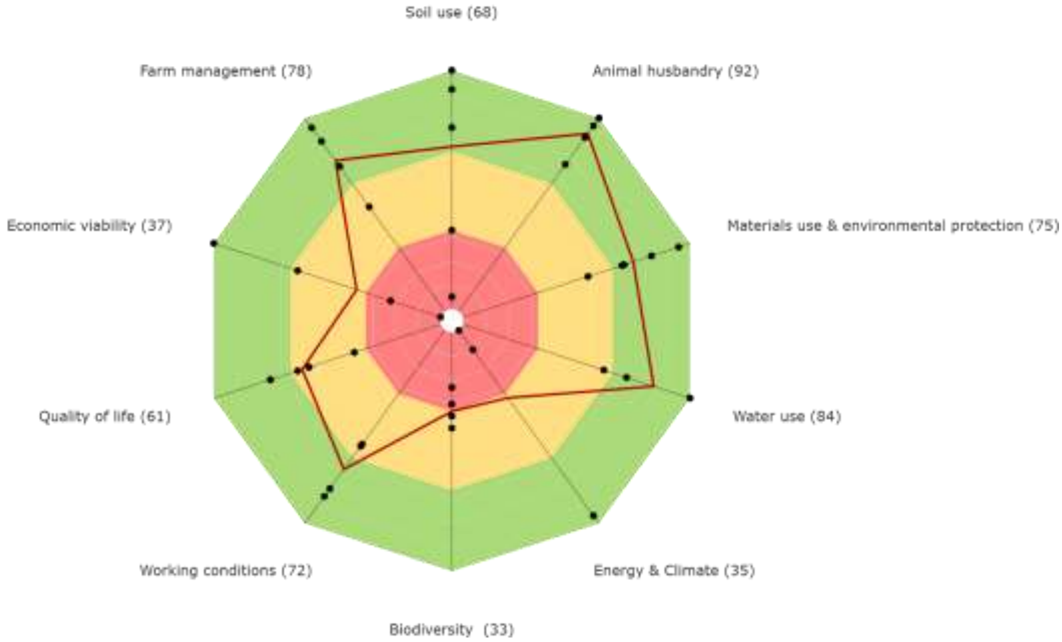

Figure 5.1: the sustainability polygon from the RISE software

In the next paragraphs, I am going to examine more in-depth each theme, analysing the obtained scores in every indicator and giving an overview of the causes and the possibility of improvements.

5.2.2.1 Soil use

1	Soil use	68
1.1	Soil management	100
1.2	Crop productivity	76
1.3	Soil organic matter	92
1.4	Soil reaction	100
1.5	Soil erosion	33
1.6	Soil compaction	5

Table 5.2: soil use indicators score

For what concerns the soil use, the overall rate is very good, but two indicators above all managed to lower the total points: soil erosion and compaction. Soil erosion (number 1.5 in table 5.2) depends directly on the composition of the soil in the areas where it has been observed and the local weather conditions. The lower Rhine region, in the North-West of Germany, is exposed to heavy winds and rainfalls for most of the year therefore the quantity of soil lost through water and wind erosion in the most threatened areas can be near the level of tolerance, which means that this is a real risk.

The soil compaction rate, in particular, is the lowest of the batch, due to the fact that the farmer uses very heavy machines (wheel load of more than 2,5 tons.), even in very moist conditions of the soil, and the composition of the soil, which contains more than 25 mass percentage of clay in it. The farmer takes some protection measures, such as lowering the tire pressure of the machine used or liming and reducing tillage when possible, but crop growth and soil life are quite affected by the over-compaction of the subsoil.

Other than that, the farmer's knowledge and the technology that he disposes of in the far are actively employed to facilitate productive, site-adapted and soil-conserving soil use. This way, soil reaction is within the optimal range for crop growth; soil use causes neither salinization nor acidification beyond this range. The arable soil on the farm is well supplied with organic matter, ensuring that the soil organic matter content in the topsoil at least remains stable. The crop area is either big or too small, therefore through appropriate yields per unit area, the farm contributes in terms of both quantity and quality to satisfy the demand for agricultural products and ensures its own economic competitiveness (Grenz et al., 2018).

5.2.2.2 Animal husbandry

2	**Animal husbandry**	**92**
2.1	Herd management	100
2.2	Livestock productivity	96
2.3	Opportunity for species-appropriate behaviour	90
2.4	Living conditions	100
2.5	Animal health	76

Table 5.3: Animal husbandry indicators score

Animal husbandry is the theme with the highest score of all, as we can see in table 5.3. In every indicator, the score is between 76 and 100, an optimum result. As it was possible to confirm during the visit to the farm, animals are regularly observed, barns are cleaned properly, frequently and thoroughly, animals with infectious diseases are separated and adequately treated, and the composition of animal groups not modified unnecessarily. Livestock populations on the farm are managed in a long-term and site-adapted manner in order to optimize animal health, animal welfare and sustainability, other than high performance.

Furthermore, information about performance, reproduction, animal transport and illness are collected and documented and used for livestock management. The animal breed is selected for robustness, adaptability to climate and farm conditions and expected life performance. This decision helps in animal welfare as the breed is suitable for the geographical zone, and it reduces the risk of unnecessary suffering.

The requirements for animal health and welfare include clean water and air (sufficient oxygen content, few aerosols, low levels of dust and harmful gases such as ammonia), air temperatures within the species' comfort zone, light and noise levels that do not disturb the animals' senses and species-appropriate, welfare-friendly feeding arrangements (Algers et al., 2009). The housing system has a major influence on all of these indicators. Humans working with the animals also benefit from improved animal housing conditions: working in a species-appropriate structure is usually both more pleasant and healthier for humans, too. In the end, the animal husbandry system provides the animals with the freedom to express their natural social, movement, resting and sleeping, feeding, excretion, reproductive, comfort and exploring behaviours (Grenz et al., 2018). The physiological needs of the animals are met, and they live in a species-appropriate environment.

5.2.2.3 Material use & environmental protection

3	**Materials use & environmental protection**	**75**
3.1	Material flows	55
3.2	Fertilization	95
3.3	Plant protection	83
3.4	Air pollution	70
3.5	Soil and water pollution	71

Table 5.4: Material use & environmental protection indicators score

Regarding fertilization of the soil, a balanced crop nutrient supply facilitates good yields while preventing damage to the environment and soil nutrient deficiencies. Optimal use is made of the nutrients available on the farm and these are only supplemented by externally sourced nutrients where necessary. Plant protection on the farm is based on the principles of integrated plant protection, which means that careful consideration of all available plant protection methods is made to subsequently integrate the appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment (Klingen, 2018). Hazardous substances that are harmful to the environment are only used where strictly necessary and their impact on the environment is minimized through targeted selection and application.

The storage, use and disposal of materials do not cause gaseous emissions that threaten or harm the health of humans, animals or the environment (air, soil, water and natural ecosystems), or at least this is prevented in every way possible, for example, using sealed storage space, or protecting the soil with concrete floors or plastic sheets. In so doing, the storage, use and disposal of materials do not cause liquid or solid emissions that threaten or harm the health of humans, animals or the environment.

The only topic that is lower than the others is material flows since the farmer promotes sustainable production of consumables, machinery, infrastructure, feed and fertilizer through responsible sourcing wherever he can, but in some cases is not possible. This is particularly valid for the feed of which 20% is sourced from all over the world, but the rest is sourced locally (within 15 km from the farm). Furthermore, targeted material selection and efficient resource utilization prevent waste, however, as the farm is made, there are many losses of feed and waste materials can hardly be recycled, unless they are disposable, which makes it easier to differentiate and recycle.

5.2.2.4 Water use

4	**Water use**	**84**
4.1	Water management	62
4.2	Water supply	100
4.3	Water use intensity	100
4.4	Irrigation	72

Table 5.5: Water use indicators score

This theme explores the use of water and how intensively and efficiently water is used for production. The results in table 5.5 show that the quantity and quality of the farm's water supply are secure in the short and long term, there have been no worries about the provision of water not now nor in the past. The quantity of water used in agricultural production is adapted to local conditions through the choice of crops and timing of cultivation. The farm is not dependent on externally supplied water and its irrigation requirements are minimized.

The irrigation methods are quite efficient and enable high physical and financial yields for the farmer. Some improvements can be made by changing the irrigation system to a more developed one since the one already there is quite old (but still functioning).

Knowledge and technology are actively employed to ensure efficient, site-adapted and resource-conserving utilization of water resources. Again, some improvements can be made using more adapted crops or irrigating only during the night, this way water will not evaporate so fast. Problematics like fields that are not precisely levelled are not easy to resolve, since it is not man-caused but more a given fact to work with.

There are numerous technologies that enable substantial improvements in agricultural water use. Examples include water collection by rainwater harvesting and flash-flood irrigation, water storage in cisterns and water application through various types of drip and sprinkler irrigation systems, including measurement and control technologies. Water use efficiency can also be improved through methods such as deficit irrigation and alternate furrow irrigation (Grenz et al., 2018).

5.2.2.5 Energy & climate

5	**Energy & Climate**	**35**
5.1	Energy management	96
5.2	Energy intensity of agricultural production	10
5.3	Greenhouse gas balance	0

Table 5.6: Energy & climate indicators score

Energy & climate is on the edge of the red zone, the topics are very different in rating and the mean is not so good after all. Sustainable energy use is facilitated through the active deployment of knowledge and technology. This indicator is only calculated if energy is actually used on the farm, as opposed to only human and animal labour. Energy consumption is monitored, the potential for producing renewable energy on the farm is being used, and the farmer is aware of the potential energy-saving measures that could be implemented on the farm and the extent to which such measures are actually being implemented. Energy demand can be reduced by using heat exchangers and heat pumps and through better insulation. Even if many measures have been implemented to save energy, it is not the same for energy consumption. The utilization intensity and the percentage of non-renewable energy carriers on the farm are calculated in the single indicator of energy intensity of agricultural production. Agricultural production is totally reliant on non-sustainable energy sources; therefore, the score is so low. The consumption of fossil fuels is heavy, mostly coming from the use of heavy machines and tractors. To this count, it must be added the consumption of machine work conducted on the farm by third parties. The part that is more easily adjustable is the electricity consumption. Since renewable energy sources have not yet been implemented, the best thing to do would be to start to include at least a small percentage of it.

The annual net GHG emissions of the area of the farm used for production exceed by far the amount that it would need to emit in order to prevent a rise in the average global temperature of more than 2°C compared to pre-industrial levels (Grenz et al., 2018). Even if some practices, such as the burning of harvest residue, are not implemented and therefore they are not adding to these GHG emissions, the use of fossil fuel and fertilizer certainly does. In this specific case, GHG emissions are mostly derived from the livestock, due to the fact that cows are the largest producer of these gasses (Poore & Nemecek, 2018), but since the farm has a big part of agricultural land the emissions derived from the use of fertilizer and fuels must be taken into account. This means that the score point is the lowest obtained by far.

Direct methane (CH_4) emissions from ruminants are calculated using the method described by Mills et al. (2003), which calculates the quantity of CH_4 based on the amount of dry matter fed to ruminants. Calculation of indirect CH_4 emissions resulting from slurry storage is based on the IPCC (Level II) approach (IPCC, 2006), which takes account of livestock species and number, ambient temperature and slurry management. The emissions resulting from slurry storage are rated as zero if the slurry is fermented in biogas plants.

The calculation of N_2O emissions resulting from nitrogen application is based on IPCC (2006) Level I. The nitrogen sources taken into account are livestock excreta minus gaseous losses during livestock production and application, mineral fertilizers, atmospheric N deposition and N fixation by legumes. It is assumed that there is no difference between N from organic and inorganic compounds (Stehfest & Bouwman, 2006).

This is the most difficult theme to renew and modify, since the emissions cannot be eliminated, at least decreased within possible, but only a limited reduction of GHG emissions will be possible if demand for agricultural products remains unchanged. Potential measures include the establishment of buffers, measures to protect against damage (like preventing erosion, flood defences, hail netting, etc.), risk spreading through diversification on the farm, such as different crops, livestock genetic diversity, permanent crops, several different production sectors and potentially income from off-farm sources, and insurance against damage (hail insurance, livestock insurance, fire insurance and invalidity insurance). Other possible improvements could be to store manure properly in closed areas to avoid the liberation in the atmosphere of these gasses and avoiding to exceed into spreading it in the crop fields (Grenz et al., 2018).

5.2.2.6 Biodiversity

6	**Biodiversity**	**33**
6.1	Biodiversity management	40
6.2	Ecological infrastructures	23
6.3	Distribution of ecological infrastructures	35
6.4	Intensity of agricultural production	35
6.5	Diversity of agricultural production	30

Table 5.7: Biodiversity indicators score

The biodiversity theme has the lowers score of all, as can be seen in table 5.7. The farm has not a biodiversity management system that incorporates a strategic and systematic approach to planning, decision-making, implementation and monitoring of activities geared towards species protection and ecosystem conservation. The farmer has a knowledge of the current situation but should be planning the implementation of species and habitat protection measures and monitoring the success of any measures implemented. A variety of farming measures to promote biodiversity should be implemented in the agricultural area to increase this score.

Sustainable agricultural production requires conscious management of the different natural resources that a farm uses and influences. As one of these resources, biodiversity is strongly affected by the methods used in production. Farmers thus have a responsibility to protect and promote biodiversity and to make sure that they do not harm it. In order to ensure that a given site's biodiversity is maintained and is not damaged as a result of unintended impacts or changes in farming practices, the farmer must have a fundamental sensitivity to and knowledge of this subject and its context. Active biodiversity management may then involve farmers obtaining external advice and support to develop decision-making guidelines and potentially also help with the implementation of measures, although this may also be done by the farmers themselves (Grenz et al., 2018). As far as rare species or protected habitats are concerned, the first step of this approach is for the farmer to be informed about the actual and potential presence of such species/habitats on the farm. The next step is to use this information to develop and implement specific individual measures. The third step is to monitor the success of the measures that have been implemented and the final step is to carry out any necessary amendments to the measures.

In addition to the planning aspects, biodiversity management also includes concrete farming measures. Different farming practices have different impacts on biodiversity. Measures that can be implemented in crop production are, for example, avoiding the use of insecticides, fungicides or growth regulators, the use of herbicides or mechanical weed control. Other examples are the use of mixed cropping of cereals and vegetables, winter planting with intercrop or green manure during winter months, measures to promote soil organisms, such as the use of manure compost, or soil-friendly crop production that avoids ploughing, till drilling and rotary band seeding. Regarding permanent crops some measures applicable are avoiding the use of plant protection products, avoiding clearing or burning practices, such as removal of standard fruit trees, cultivating resistant fruit varieties, reducing the use or use of nature-friendly plant protection products in fruit cultivation, leaving brush piles, rock piles, woodpiles, wild bee hotels and lacewing boxes (Grenz et al., 2018).

The ecological infrastructures indicator reflects the percentage of the farm area that has a high ecological value. Only the area used for agriculture is assessed and the ecological value of the various areas is estimated by the farmer. Protected status, participation in agri-environment schemes and comparisons with reference photos can yield useful information about whether an area is ecologically valuable. The score is so low because the farmer is not participating in any of the schemes previous named.

A plus point must be hives presence. Honeybees and other insects contribute to the value of farm harvests by pollinating crops and wild plants. In addition to the direct benefits of pollination, beekeeping can also be expected to provide indirect benefits, since bees require a continuous supply of flowering plants, something that is more commonly found in small-scale landscapes. The presence of honeybees also requires farmers to take particular care over which plant protection products they use.

The total points gained in this theme are low due to the fact that, apart from beekeeping, the farmer has very standard agricultural production, and also livestock breed is not a traditional breed. Crops are cultivated always in the same way (cereals, roots, legumes), no vegetables are included, and no old or endangered varieties are used. Through diverse agricultural production and on-farm use of genetically diverse crops and livestock, the farm should contribute to the survival and development of plant and animal genetic resources. This helps to ensure that a wide diversity of primary genetic material will still be available to future generations for breeding purposes. By growing different types of crops, the farm helps to create a more diverse cultivated landscape. Farms that grow ancient, local, endangered and/or disease-resistant fruit, vegetable or cereal varieties make an important contribution to crop genetic diversity conservation.

5.2.2.7 Working conditions

7	**Working conditions**	**72**
7.1	Personnel management	82
7.2	Working hours	59
7.3	Safety at work	86
7.4	Wage and income level	60

Table 5.8: Working conditions indicators score

Good personnel management ensures that the farm has a sufficient short, medium and long-term supply of satisfied, motivated and adequately trained personnel. There is little potential for conflict thanks to transparent and fair terms and conditions of employment. Appropriate measures are taken to ensure that the number of work-related accidents and cases of illness on the farm are minimized. Children are not harmed by any work they do on the farm.

The overall working conditions on the farm are good leaving some space for improvements in working hours and wages.

Many persons working on the farm do not have enough free time to recover physically and mentally, so it is hard to remain healthy and productive in the long run. This weighs more on employees rather than the farmer itself since he really likes his job and does not mind if it requires more time per day. Regarding the wages, the people employed to work on the farm should earn an hourly wage that allows them to live comfortably above the poverty line when working normal hours. In this specific study is true in the way that it gives them enough money but not enough free time. Self-employed workers, mainly family members who are not paid a wage, also receive appropriate hourly compensation and the farm delivers a positive financial return. Of course, improvements can be made, but many factors are not depending on the farmer's direct decisions but rather on the market fluctuations and this gives somewhat insecurity.

5.2.2.8 Quality of life

8	**Quality of life**	**61**
8.1	Occupation & Training	58
8.2	Financial situation	38
8.3	Social relations	63
8.4	Personal freedom & values	58
8.5	Health	75
8.6	Other areas of life	75

Table 5.9: Quality of life indicators score

Most of the farm personnel are satisfied with their occupation and their initial and ongoing training overall, the initial training is mandatory for every new employee and ongoing training like courses or self-study is also important but limited to the owner of the farm who also takes the ultimate decisions.

The farmer is asked how important social relations are to him and how satisfied he is with the current situation in this regard. He stated that this job is very time-consuming, so there is not so much space for free time and therefore he cannot attend many social events, but after all, he likes his job, so this area is not so important for him and has not the same value as others.

Ultimately, most of the farm's employees, and also the owner, are satisfied with their social relations, type of work, working hours, workload, health situation and relationships. The most critical indicator is the financial one since the workload on the farm is dictated by the needs of the fields and animals, and not always the wage reflects the effort of the workers.

5.2.2.9 Economic viability

9	**Economic viability**	**37**
9.1	Liquidity	22
9.2	Profitability	0
9.3	Stability	63
9.4	Indebtedness	0
9.5	Livelihood security	100

Table 5.10: Economic viability indicators score

The farm's liquid assets are not sufficient to meet its financial obligations at all times, as displayed in table 5.10.

An assessment is made of the ratio of cash reserves (liquid assets plus available credit lines) to average weekly expenditure (annual expenditure divided by 52 weeks). The farm's reserves are deemed not to be sufficient. Liquidity gets a very low ranking since the number of weeks that the farm can live off its cash reserves is not sufficient in the long term, the estimated time is 8 weeks. The farm has optimal economic viability if, at any time in its production cycles, it is able to pay wages and salaries, accounts payable to suppliers, loan repayments and interest payments out of its own reserves.

The farm is not at all financially profitable on either a short- or long-term basis. In other words, its earnings do not allow it to meet its financial obligations, make investments and earn a profit that adequately recompenses the equity invested in the business.

The level of indebtedness is really problematic, the financial resources are not enough to fully repay the farm's debts with its current cash flow. The score is zero because the percentage of cash flow that is currently used to service debts does not leave any leeway to take on more debt in the short term, for example, to get through a period when the market is unfavourable or to make new investments, and the number of years that would be required to refund any loan or debt is over 20 years. It is highly recommended a consult with a financial professional to improve the situation.

At the moment, the farm is quite financially stable. This means that it is regularly able to break even over a period of a few years with a normal level of household consumption but the long-term future of production on the farm is not secured. The farm has to maintain a modern infrastructure, and it is not easy considering the difficulties in the financial aspect. However, is a very relevant aspect to continue to invest in and keep up with the new technologies in order to have the lowest impact possible on the planet while at the same time aiming for better performance. Guaranteed land access means that it is possible to plan and ensure the continuation of production on a long-term basis, whilst a high equity ratio allows the farmer to make their own decisions about how the business evolves.

Compared to the rest of the indicators, the farm's income is totally sufficient to secure the economic livelihood of the household. The evaluation of the ratio between private spending and a corrected minimum subsistence level is extremely good. The minimum subsistence level is corrected for the size of the farmer's family and any payments in kind received by the farm are deducted. The private spending of family members who are not paid a wage should clearly exceed the minimum subsistence level.

5.2.2.10 Farm management

10	**Farm management**	**78**
10.1	Business goals, strategy, implementation	75
10.2	Availability of information	95
10.3	Risk management	54
10.4	Resilient relationships	88

Table 5.11: Farm management indicators score

The farmer, responsible for managing the farm, consciously sets goals, develops strategies to deliver these goals and implements the relevant measures as far as the financial aspect is covered. In this context, “conscious” means compatible with people’s personal values and the conditions on and around the farm. The chosen strategy should have a positive impact on economic, social and environmental sustainability. Indicator 10.1, shown in table 5.11, covers both the rational (planning and forecasting) and subjective (values) aspects of the farmer’s strategic development process. The goals, strategy and implementation challenges are analysed, and the business objectives are checked for compatibility with sustainability goals. The ranking is quite high, meaning that the farmer has well-thought-out goals and an appropriate strategy for the farm but lacks in the implementation part since is not made it directly. These aspects are evaluated both by the farmer, asking the rate of satisfaction with how he manages the farm, and the extension agent. The strategy is also assessed in terms of how holistic it is, considering, for example, whether it takes social and environmental aspects into account as well as economic aspects.

Moreover, where necessary, the people responsible for managing the farm have access to adequate information and reliable planning tools so that they are able to manage the farm systematically and professionally. The farm’s internal and external relationships are managed in such a way as to provide a sound basis for its long-term success. The farm cooperates with colleagues and neighbours wherever it makes sense to do so. Conflicts are resolved by consensus and not by coercion.

Indicator 10.3 has the lower score of the bunch. The people responsible for managing the farm are aware of the risks and dependencies that could pose a threat to the farm’s livelihood. There are a number of risks that can determine whether a farm succeeds or fails, the main one regarding crop failure or problems with the livestock. It is therefore important to regularly review the internal and external risks to the business and implement risk minimization measures in order to guard against adverse events. On a social level, cooperation between farms can play an important part in risk management (Pulfer & Lips, 2010). The cultivation of stable relationships can lead to the establishment of a social network that helps farms and jointly overcomes crises that threaten their livelihood or prevents the crisis from occurring in the first place. At an agroecological level, the risk of total failures can be reduced by employing a higher number of different livestock and plant species, since every species responds differently to pests, adverse weather events or shortages. This indicator assesses how the farmer deals with these risks. The score is obtained by evaluating how much room for manoeuvre the farm management has internally, particularly in terms of risk prevention but also in terms of minimizing the negative impacts of any adverse events. The implementation of quality assurance measures is key to guaranteeing healthy and marketable produce.

To conclude, the farm manager is overall aware of the current state of his farm, he pays careful attention to his farm system and keeps updated on new measures to be implemented, new technologies that can be used to improve profitability, and income while also having sustainability in mind. Of course, sustainability is restricted to the economic viability of the farm and the satisfaction of employees and landowners, and even if the farm is sensible to market fluctuations and unpredictable weather events, using a sustainability performance tool has been helpful for the farmer to better understand the areas available for improvement.

The farmer seems to be very friendly and pleasant, he has a very positive attitude, well-disposed to the project and proactive towards sustainable innovation.

Regarding the project results, most areas of the farm are arranged in the green area of the sustainability polygon but none of them has very high scores. This implies that areas with lower scores affect the overall average, reducing it to 63.5 points (Yellow zone). It must be said that two of the areas with the worst score, Quality of life and Economic viability, do not depend directly on the farmer’s decisions, indeed, these areas are highly influenced by the market fluctuations or the fact that they are in the agricultural sector. On the one hand, the primary sector is known to be the most financially at risk since it strictly depends on the weather and climate conditions, but also the domestic politics in development has its importance and is often overlooked in favour of international technocratic consensus. This view is supported by recent experience with Covid-19 where responses varied widely depending on domestic politics and the personal beliefs of domestic leaders (Dorward & Giller, 2022).

On the other hand, Quality of life is a theme that is strictly personal, it depends very much on the value that everyone attributes to each area of his life, but it is known that the agricultural sector is not the best in terms of remuneration and free time. Moreover, recent advances in Artificial Intelligence have made it possible that some skilled and unskilled labour may receive lower incomes and wages, especially for repetitive tasks, which will have implications for agricultural workforces and farm and non-farm labour markets. Although new technologies often open up new jobs, artificial intelligence will encourage economies of scale and disfavour smallholders, while depressing demand for traditional skills even more in the future. (Dorward & Giller, 2022).

The worst scores were obtained under Energy & climate and Biodiversity themes, on which the farmer can act directly. The main problem is the poor economic viability that does not allow improvements in any field. The importance of safeguarding crop biodiversity, both in situ and through gene banks, should be known to every farmer. A large part of biodiversity loss is a direct result of the change in land use resulting from agricultural development. The lack of biodiversity can cause problems not only from an environmental point of view but also from a productive one. In fact, native species suitable for growing land normally cause less damage to the soil in the long term but are less productive than genetically selected breeds or species. This theme is controversial because it is good to safeguard biodiversity, but this cannot happen at the expense of profits.

As for Energy & climate, the best choice for the farmer would be to start by implementing a set of solar panels on the rooftop of the farm, in order to be able to use renewable energy instead of relying 100% on fossil fuels. If this is not possible yet due to the scarce financial resources, then it would be advisable to look for electricity operators that provide renewable energy or still try to minimize the use of agricultural machinery that uses fossil fuels.

RISE proved to be a valid indicator-based tool to evaluate the sustainability performance of a single farm. To improve the quality of the outcomes, the suggestion is to consult with experts in the problematic fields, so the farmer will have better and more effective advice to incorporate into the farm.

5.3 Case #2: Poultry farm

Another RISE study had to be conducted on an Italian poultry farm.

Chickens are the most numerically reared animals on earth and their production will continue to increase, as stated in the previous chapter, as it is the most requested meat in the world since the meat has a fairly neutral taste that goes well with spices and seasonings and does not suffer any religious limitation (Baltic & Boskovic, 2019).

Although they are small animals, their huge number makes the farms equally polluting and dangerous for the planet as other livestock, and since the breeding of poultry is very popular in Italy, and especially in the area under consideration, the idea was to use this subject for a RISE analysis, in order to test the effectiveness of the software under conditions different from those previously used.

5.3.1 Materials & methods

The poultry farm is settled in Emilia-Romagna, a region in the north centre of Italy. It is a broiler farm mainly led by the farmer and his wife, with the help of a few employees during the washing cycles. The farmer stated that this is not his main job, but the family home where he lives, which is close to the livestock area, had several sheds used for breeding, therefore he renewed two of them to keep the breeding tradition going. The farm's dimension is suitable for the family size, there are two sheds of 16000 m^2 each in which the animals are kept for all the breeding period and there are 2 hectares of agricultural land.

The rearing of broilers has short cycles, of a maximum of 49 days, during which the sheds are full and busy with about 15000 heads per shed. They are not caged, but not able to graze outside the shed either, so they are reared on the ground. The breeding is intensive, as the circadian rhythms are dictated by lamps and automatic light intensity. The light and dark periods are adapted to the age of the broilers, but overall standardized. At the end of the breeding period, the broilers are transported to the slaughterhouse and the sheds must be cleaned, washed, sanitised and left empty to aerate for a period of 14-21 days. It is at this time that the farmer gets help from some employees, who are shared with other neighbour farms since the workload only requires a small period of time.

The RISE project started as the German one, with the explanation of the software and the submission of the questionnaire, followed by a tour of the farm.

5.3.2 Results and discussion

Unfortunately, when filling out the questionnaire, the farmer announced that the fields around the sheds have not been cultivated for almost 5 years. The main reason they have fallen into disuse is that the area is too small to be financially profitable. As noticed during the farm visit, the arable land is no more in use, but it is not damaged at all. The farmer continues to keep it clean from weeds, but he decided to stop all sorts of cultivations since there was no profit at all and, on the contrary, he could barely cover the costs of cultivation. This caused a lot of problems in terms of the success of the analysis due to the fact that the majority of data could not be obtained at this point. The software is based on the combination of animal husbandry and agriculture to evaluate the overall activity of the farm and occasionally some themes can be excluded from the final overview, if not relevant, but in this specific case the foundation of the whole program has been lost since out of 10 themes, the questions answered were able to bring results just for 2 of them. However, even if in an incomplete scheme, some data have been obtained, and for this reason, some indicators can be discussed.

Regarding Animal husbandry, there are a few issues to point out. The questions were designed for large animals, such as cattle or sheep, which require a lot of space and diverse areas to perform different behaviours. Poultry, on the opposite side, are a gregarious species, but quite static after all. It is quite common that in a breeding shed the animals stay in the area where they grew up and that therefore if they are on one side of the shed, they will not go to the opposite one, or at least is very rare. Chickens sleep close to each other, so they compact during the night and start spreading out before the sunset. Chickens also have a desire to roost. At about three weeks of age, chicks start to jump up to higher surfaces. The structure of a chicken's claws ensures a firm grip while the chicken is perching and will prevent the chicken from falling off a tree branch, even when the bird is asleep (Wood-Gush, 1955). Hence, poultry do not need specific areas in which to rest, but rather some raised perch to meet their needs. Also, their life lifecycle is very short compared to other animals. This is not taken into consideration when it comes to the question list in the questionnaire, nor is the time needed to clean the barns or when they are left empty. Therefore, the results can be flawed or non-representative when it comes to poultry livestock.

In the field of energy, the company is on the right track. Since the sheds have recently been renovated, solar panels have also been installed on the roof, thus ensuring a percentage of renewable energy that significantly reduces the external supply. On the other hand, however, gas is used for heating the breeding area and a hydraulic cooling system to reduce temperatures in the warmer months. The gas in particular adds to the GHG emissions derived from the livestock, which brings down the potential final score.

There may also be improvements to be made regarding water resources and their use. The water used for the cooling system is recycled from other activities, but it is not rainwater since the farm is not equipped with collection tanks. Instead, the water used for animals and for washing comes directly from the aqueduct. Thus, there are no supply problems, but the water during the cleaning process can be wasted or polluted with soaps and detergents.

The main problem with the application of the RISE software was found in the structure of the farm. In fact, the farm taken into account is not a real farm, as not only it does not use its productive agricultural areas anymore, but also has little margin for decisions on many logistical and practical aspects. This is primarily because of the integrated supply chain. Vertical integration means that a firm can extend its influence by taking over key steps in the whole supply chain. This is particularly true for the poultry chain, since it is quite easy to incorporate feed mills, hatcheries, breeder farms or rearing of laying hens, and processing plants, even if they are geographically spread in a large area. On the one hand, the deep integration of the poultry chain, through continuous exchanges of raw materials and resources makes both agricultural and livestock systems more efficient and sustainable from an economical point of view (Manning & Baines, 2004), but on the other hand, is not at all aligned with the RISE analysis needs. In fact, more and more small farmers are included in these arrangements, which typically involve agreements in which the farmer or landowner provides the housing, equipment, and labour, while the big company provides the chicks, feed, medication, transport, and supervision (FAO, 2013). This happens more and more frequently since the small farms cannot sustain themselves in the growing market and the only way to survive is to consent to those agreements. This means that the farmer itself is not aware of every aspect required from the questionnaire or may not be able to change anything without the company's permission, and this is equally failing for the aim of the project. A way to overcome this problem could be to previously inform the farmer about the questions and give him time to retrieve all the necessary information, otherwise letting more people of the company to take part into the questionnaire.

5.4 Conclusions

Within this master thesis, various aspects related to the issue of sustainability in the food sector were addressed, starting from a description of the current situation in the world, considering the continuous increase in population and greenhouse gas emissions and looking for possible improvements toward the problems.

The increment in population number and wealth is directly related to the growing demand for meat products, which is, in turn, related to an increase in greenhouse gas emissions. Consumers are becoming more and more aware of these environmental issues and are increasingly demanding transparency and good actions from the companies in the market. Sustainability factors are becoming even more relevant from the environmental point of view, so much so that world organizations, like FAO and UN, are also implementing measures to ban or reduce some polluting practices while, at the same time, setting future goals to pursue.

Considering the fact that the livestock sector is the largest contributor to the total greenhouse gas emissions in the food chain and the importance that the sustainability aspect is assuming in food companies, the need to determine somehow the overall sustainability of a business has been manifested. A tool that can be used to objectively measure sustainability on a farm is the Response-Inducing Sustainability Evaluation (RISE).

The RISE software processes the information obtained through an interview with the farmer, in which a questionnaire is submitted with questions regarding 10 different areas that range from energy to biodiversity, water use, and livestock management called themes. For each theme, the results are expressed clearly with a score that goes from 0 to 100. The experimentation discussed in this work included two different projects, one regarding a dairy farm and the other regarding a poultry farm.

The case study carried out with the dairy farm gave results that were discussed with the farmer. Overall, the farm has an average score, leaving room for improvement in several areas, like biodiversity and energy and climate. The owner is aware of the current state of his farm and is open to adopting the suggestions given for improvements. RISE demonstrated to be a valid indicator-based tool to evaluate the sustainability performance of a single dairy farm. The use of the software is proven in cattle and sheep farms, as many other projects have been carried out in this field by other people, expanding the reference database and therefore making the data valid and reliable.

On the other hand, the performance on the broiler chicken farm highlights some incompatibilities between the software and the poultry supply chain. This is due to the fact that, from a design point of view, RISE does not take into account the significant differences that exist between cattle and poultry farming, both from a management and husbandry point of view, therefore many aspects are not taken into consideration or are not sufficiently examined in depth.

To conclude, RISE is an important tool that can be used to measure the sustainability of a farm, despite the fact that it has limits regarding the poultry sector. This does not undermine the quality of the project or the functioning of the software but makes it less efficient since it is applicable only in some cases. An important future development could be to extend the program and expand its field of use to poultry, or to implement a set of more detailed questions in the questionnaire so that the project can also be carried out successfully on poultry farms.

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