From Livestock to Fellow Creature: The Potential of Multifunctional Animal Husbandry for Sustainable Agriculture

Alexander Greiner

Abstract

This study examines the concept of multifunctional animal husbandry (MAH) as a sustainable future model for cattle farming in Germany. Criteria for defining and evaluating MAH were developed, and a comparison with conventional farming systems was conducted. MAH showed the highest sustainability potential in the areas of society, ecology, and animal welfare. The calculated production potential of MAH could meet the nutritional requirements for milk (604-965 g daily) and the current consumption of beef (147-235 g weekly) in Germany. The study proposes a multifunctionality degree of over 60% as a target value for sustainable livestock farming. The results suggest that MAH represents a promising alternative to current farming systems and could solve sustainability issues. Further research on practical implementation and transformation pathways is recommended.

Keywords

Sustainability, multifunctionality, livestock farming, cattle, animal welfare, circular economy

1 | INTRODUCTION

The world's population is growing, and with it the demand for animal products (UN 2022; FAOSTAT 2023). However, modern livestock farming is already causing ecological, social, and animal ethical problems. Many farm animals live separated from their natural habitat (BMEL 2019; Destatis 2021a; Destatis 2021b), and only a few high-performance breeds dominate production (Destatis 2023). Consequently, livestock only perform isolated functions and fundamentally remain mere raw material suppliers. Economic interests often take precedence over animal welfare, although farm animals in Germany and Europe are legally protected and recognized as sentient beings (including Art. 13 TFEU; Art. 20a Basic Law for the Federal Republic of Germany, German Animal Welfare Act). In anthropocentric thinking, farm animals thus occupy only a marginal position. But could the well-being of animals and the future of humanity be more closely linked?

Even though livestock play an important role in global protein supply, not all farming systems increase the efficiency of the food system (van Zanten et al. 2018; Mottet et al. 2017; Wilkinson 2011; Wilkinson & Lee 2017). By exclusively using grassland and industrial by-products and residues, it can develop ecological and social benefits and make a positive contribution to food supply (Schader et al. 2015). However, especially industrial animal husbandry turns livestock into food and land competitors by feeding them crops edible to humans, which are used to increase production quantities.

By using 70% of German (Jungmichel et al. 2020) and 76% of global agricultural land (Mottet et al. 2017), livestock farming is inevitably one of the biggest drivers of anthropogenic climate change, loss of biodiversity, and soil fertility within agriculture (cf. Benton et al. 2021; Steinfeld et al. 2006). Moreover, excessive meat consumption causes health problems (Sun et al. 2021; Song et al. 2016; Battaglia Richi et al. 2015), and other dangers such as antibiotic resistance and zoonoses could increase due to intensive livestock farming with genetically homogeneous, geographically concentrated, and disease-prone livestock populations (van Boeckel et al. 2017, ECDC et al. 2021; Liverani et al. 2013: 876; Hayek 2022).

It shows that today's intensive systems are one-dimensional and neglect external effects. Nevertheless, the efficiency of the system is still mainly judged by productivity and competitiveness on the world market, rather than being oriented towards actual nutritional needs, food security potential, animal welfare, or environmental and social criteria. Holistic concepts are lacking, that not only treat symptoms and stylize further industrialization as the only solution (see WBA 2015; BMEL 2019) to protect current production practices and consumption patterns. The increasing efficiency and the dream of more modern barns with more technology have existed for decades without having been a long-term solution so far. Through the rebound effect, it may have created the current situation and enabled the increase in meat, egg, and milk consumption. But what could a sustainable livestock farming look like that represents the interests of humans, animals, and the environment?

This article presents the concept of multifunctional animal husbandry (MAH), which places the animal as a fellow creature and its diverse functions at the center of sustainability assessment. Using the example of cattle farming in Germany, the potential of MAH is analyzed in comparison to common husbandry systems. The aim is to examine MAH as an alternative solution, also in comparison to current state measures, and to derive target values for sustainable livestock farming. Such an analysis of the potentials and consequences of a physiocentric approach, which puts the animal and not humans at the center, has been lacking so far.

Definitions and explanations

Multifunctionality

The analysis of multifunctionality recognizes two approaches. One interprets multifunctionality as an attribute of economic activity, characterized by the simultaneous production of diverse, interconnected goods, services, or effects. These can be positive or negative, intended or unintended, complementary or contradictory, reinforcing or balancing. Some of these goods and services are valued in the market, while others are beyond market mechanisms (OECD 2001).

According to the normative concept of multifunctionality, agriculture has assigned multiple roles and is tasked with fulfilling defined societal functions. Thus, multifunctionality is not merely a property of the production process but has value in itself. Consequently, the goal of policy can be to preserve or increase the multifunctionality of an activity (ibid.).

The focus was placed on the direct functions of animals to avoid overlap with the concept of sustainability.

Food Security Potential

Preservation and improvement of fertile soils as a long-term foundation for agricultural production and maximization of food and production reserves through adapted eating habits and efficient cultivation.

2 | METHOD

After a literature review, the study first defined multifunctional animal husbandry (MAH) based on seven functional areas that livestock can fulfill. In addition to the production of raw materials such as milk and meat, these include aspects such as landscape maintenance, utilization of grassland and residues, or the preservation of species diversity in livestock (Figure 1). Cattle were chosen as an application example because, as ruminants, they play a central role in a circular food system, especially for grassland use (Schader et al. 2015), and have the highest efficiency with feed not suitable for human consumption (Mottet et al. 2017; Wilkinson 2011; Wilkinson & Lee 2017).

To evaluate the sustainability of MAH compared to common husbandry systems, 46 criteria from the areas of ecology, economy, society, and animal welfare were created and used. They reflect the current situation and possible future developments and risks.

System Comparison

An evaluation matrix was then used to compare (based on literature references) MAH with four husbandry forms - a basic and a premium system each for dairy cows and fattening cattle. The comparison systems are based on systems level 0 and 3 (corresponding to husbandry levels 1 and 4) from the Thünen report on policy impact assessment of the recommendations of the Livestock Farming Competence Network by Deblitz et al. (2021). The basic system representatively reflects current farm structures in Germany; the premium system is a future alternative according to current animal welfare goals and corresponds in terms of housing to the EU organic regulation (Figure 2).

The **basis of MAH** are two premises: (1) the welfare and health of the animals have top priority for maximum multifunctionality and the long-term performance of the functions, and (2) the highest welfare is to be achieved in a natural living environment and social structure.

Consequently, the natural behaviors and needs of the animals must be met. The defined system was designed accordingly. For cattle as ruminants, adapted to soft grounds, whose natural diet consists of 70% grass, 20% herbs, and 10% leaves and tree growth (Bell 1997 according to Brade & Brade 2017a), this means year-

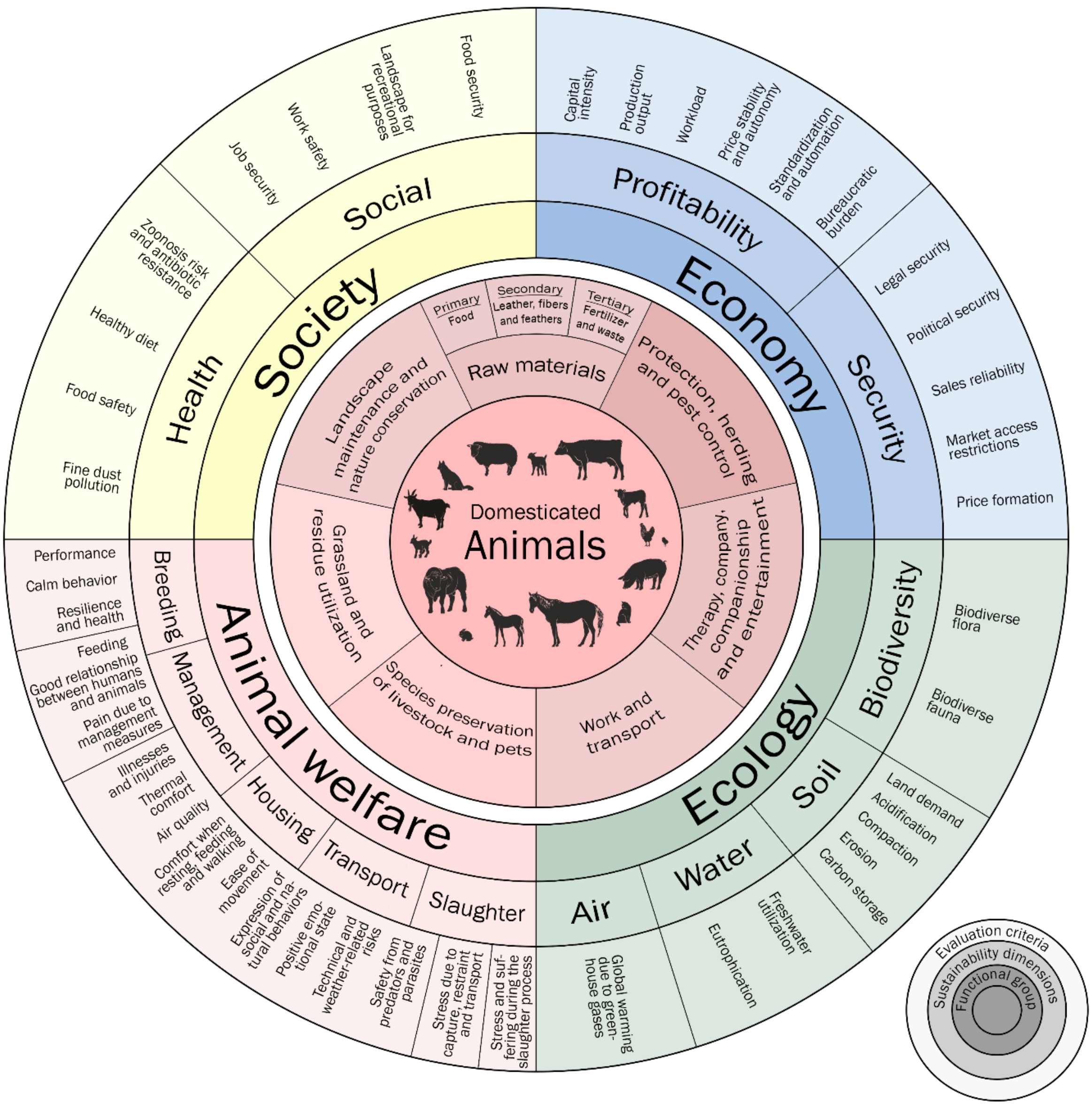

Figure 1: Sustainability circle of multifunctional physiocentric animal husbandry

round grazing with fixed herd structures (Reinhardt & Reinhardt 1981; Putfarken et al. 2008) and providing calves with sufficient whole milk - ideally cow-bound calf rearing. Additionally, the cattle are slaughtered on the pasture and only transported in emergencies to prevent stress. All cattle are genetically adapted to their respective environment.

Based on the evaluations of the individual criteria, a sustainability value on a scale of 1-5 was calculated for each system. It represents the estimated effect on the individual criteria in relation to each other (in the absence of an absolute reference) from positive to negative. Additionally, the degree of multifunctionality (0-100%) was determined, which expresses how extensively the various functions of the animals are used in each case.

Production Potential

Finally, an estimation of the production potential that MAH could realize in Germany was calculated. For this, the available grassland and arable land for necessary crop rotations, as well as the accruing plant residues from the food industry (resulting from the production of flour, starch, edible oil, beer, and sugar) were used as the calculation basis (see appendix). Necessary crops in rotations go beyond the self-purpose of animal production and are required for long-term soil fertility or provide ecological benefits. These include fodder crops such as clover grass, alfalfa, or legume mixtures, which can be incorporated into arable crop rotations for weed control, humus enrichment, and nitrogen fixation (SMUL 2008).

Two scenarios were created showing the minimum and maximum production quantities - broken down by available energy and protein amounts in feedstuffs (see appendix).

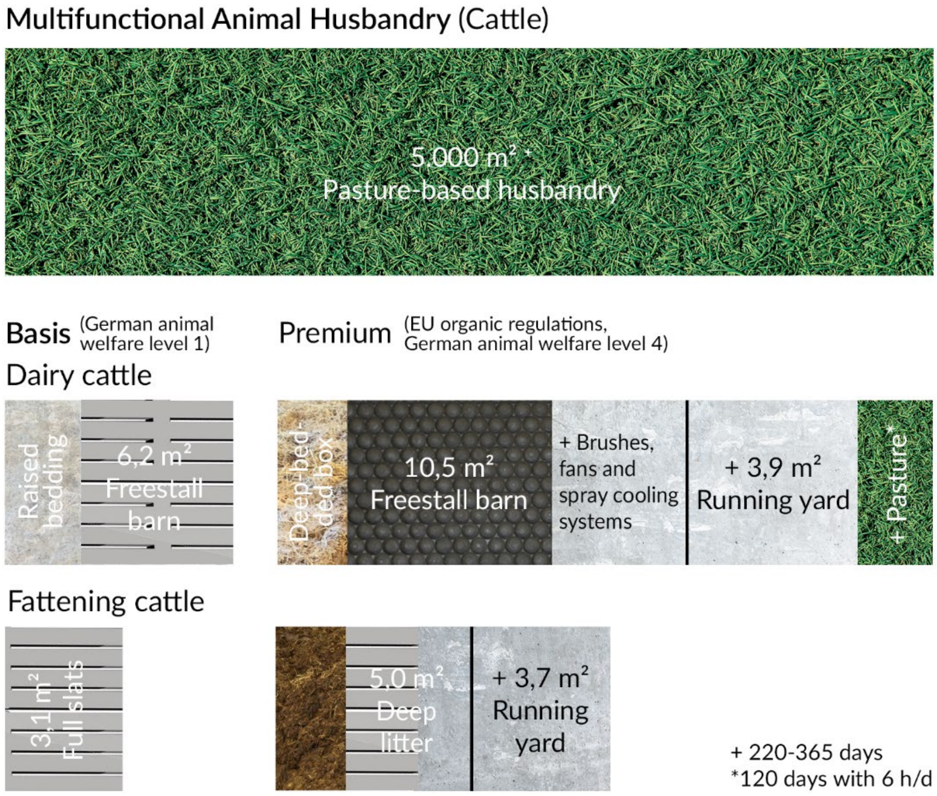

Figure 2: Overview of the system comparison

$$\text{Production Potential} = \frac{\text{Grassland Potential} + \text{Residue Potential} + \text{Crop Rotation Potential}}{\text{Feed Requirement}}$$

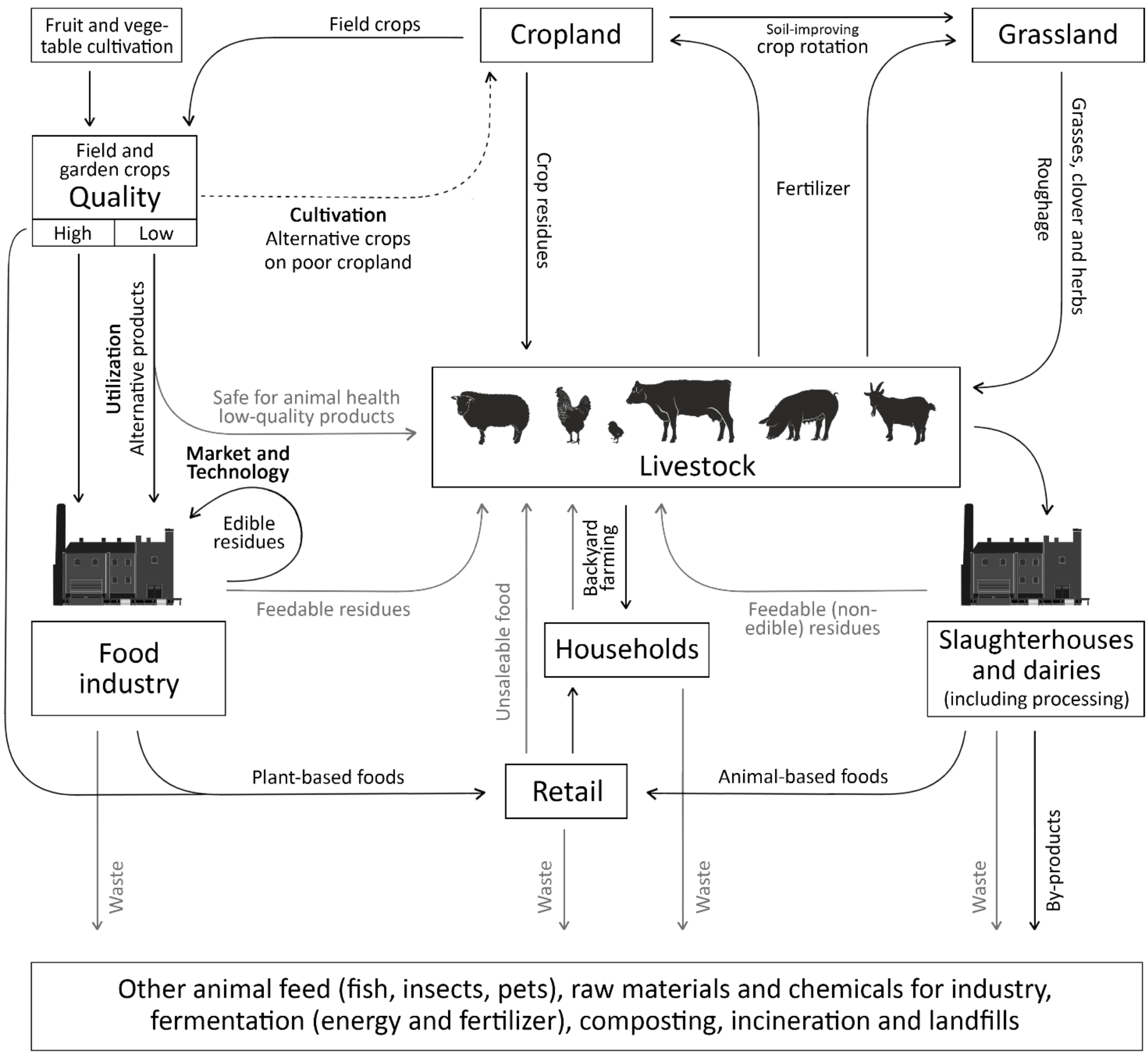

Figure 3: Flowchart of multifunctional animal husbandry as part of a future circular economy with exclusive use of non-edible biomass as feed and minimization (grey paths) of waste and residue flows (through technology, market, recycling and cultivation) as well as outflows from the food system

3 | RESULTS

The study defined seven functional areas that livestock can potentially fulfill. In the western context of cattle farming, the focus is on the first four functions: Raw materials, landscape maintenance and nature conservation, grassland and residue utilization and species conservation of livestock and domestic animals (Figure 1). This revealed a fundamental conflict of objectives between the production of raw materials and the other functions such as landscape conservation or grassland utilization. The more intensive the production, the less the other functions come into effect.

System comparison

In comparing the examined systems, MAH achieved the highest degree of multifunctionality at 62-67%. The combined current husbandry systems reached 50-53%. The basic housing systems for dairy cows and fattening cattle had the lowest values at 22-31% and 21-27% respectively (Table 1). MAH also performed best in terms of sustainability criteria, with an overall score of 3.9. It achieved scores of over 4 in the areas of animal welfare, ecology, and society, while the comparison systems reached a maximum of about 3.4. Only in the economic area did the comparison systems have an advantage with values of 3-3.5 compared to 2.5 for MAH (Figure 4; Table 2).

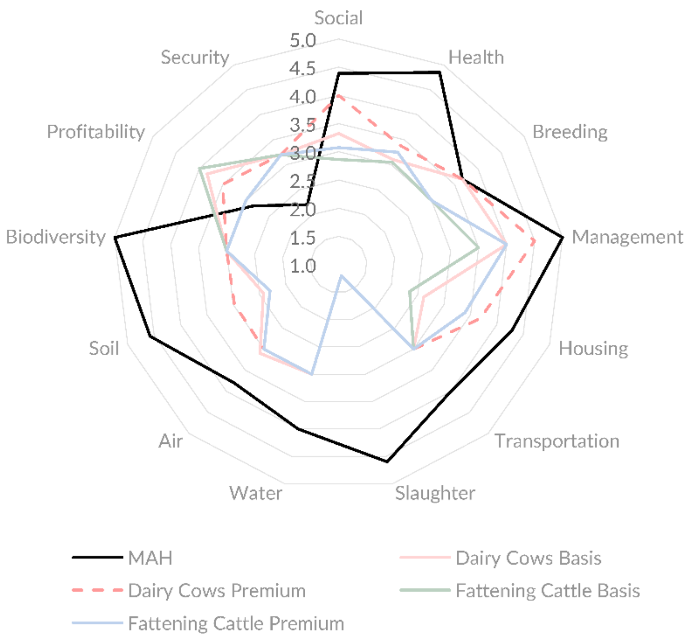

Figure 4: Detailed overview of the sustainability values of the comparison systems

Table 1: Simplified multifunctionality degree in comparison

Function	MAH	Dairy cows Basis	Dairy cows Premium	Fattening cattle Basis	Fattening cattle Premium	Combination [e] Basis	Combination [e] Premium
Raw materials (50 %)							
Milk volume (kg) [c]	5,500	9,200	8,200	0	0	9,200	8,200
Slaughter weight (kg)	318	371	371	450	450		
Quantity of meat per year (kg slaughter weight/a) [c]	127	74,2	74,2	260	260	334	334
Age at sale (days)	730 [d]	1,825 [d]	1,825 [d]	570	570		
Intermediate value (%)	43.4	45.3	41.5	37.1	37.1	82.4	78.6
Nature conservation and landscape management (15 %)							
Grazing duration (d/y; h/d) [c]	220; 24	0	150; 6	0	0	0	75; 6
Grazing intensity (Livestock unites/ha)	2.1	0	10.0	0	0	0	5.0
Intermediate value (%)	75.0	0.0	17.0	0.0	0.0	0.0	8.5
Grassland and residue utilization (25 %)							
Proportion (DM) of grassland and plant by-products and residues in the ration (%)	100	38.1	64.4	40.2	45.8	39.2	55.1
Intermediate value (%)	100.0	38.1	64.4	40.2	45.8	39.2	55.1
Conservation of livestock and pets (10 %)							
Proportion of endangered breeds (%) [a]	50	3	3	6	6	4.5	4.5
Intermediate value (%)	50.0	3.0	3.0	6.0	6.0	4.5	4.5
Degree of multifunctionality unweighted	67.1	21.6	31.5	20.8	22.2	31.5	36.7
weighted [b]	61.7	30.6	37.3	27.2	28.3	49.5	52.5

[a] Maximum estimate after evaluation of livestock by breed 2022 (Destatis)
[b] The weighting factor is shown in brackets after the function
[c] The assumed production maximum for milk is 13,270 kg milk/cow/a and for meat 350 kg carcass weight/a. The grazing duration for the assumed maximum is 2640 h/a (220 days x 12 h) and is based on the vegetation period in Germany in 2021 (DWD 2022 according to UBA 2022).
[d] MAH does not refer to the production life of dairy cows, as is the case with Basic and Premium dairy cattle, but to the slaughter age of fattening cattle. The heifers either replace the dairy cows after two years or are slaughtered. The production life of dairy cows in the MAH is higher.
[e] Treatment of dairy and fattening cattle as a closed, combined system.

Table 2: Overview of the system comparison of the sustainability criteria (for explanations of the assessment see technical appendix in Greiner 2023)

Dimension		Criteria	Direction	MAH	Dairy cows		Fattening cattle	
					Basis	Premium	Basis	Premium
Society	Social	**Food security**	↑	++	o	+	-	-
		Competition for food and land	↑	++	o	+	-	-
		Availability and economic access	↑	-	++	+	++	+
		Landscape for recreational purposes	↑	++	-	o	-	-
		Work safety	↑	o	++	++	+	+
		Job security	↑	++	o	+	o	+
	Health	**Zoonosis risk and antibiotic resistance**	↑	+	-	o	-	o
		Entry risk	↑	o	+	o	+	o
		Exposure risk and spread	↑	+	-	o	- -	o
		Use of antibiotics	↑	++	-	o	-	o
		Healthy diet	↑	++	o	+	-	-
		Damage to health due to consumption quantity	↑	++	o	o	- -	- -
		Health benefits	↑	++	o	+	o	o
		Food safety	↑	++	++	++	++	++
		Fine dust pollution	↑	++	-	-	o	o
Animal welfare	Breeding	**Performance**	Goal	-	++	++	++	++
		Calm behavior	Goal	+	o	o	-	-
		Resilience and health	Goal	++	o	o	-	-
	Management	**Feeding**	↑	++				
		Good relationship between humans and animals	↑	++	++	++	+	+
		Pain due to management measures	↑	++	o	+	o	+
	Management / Housing	**Illnesses and injuries**	↑	++	-	+	-	+
		Hoof and limb diseases	↑	++	-	++	-	+
		Udder health	↑	++	o	+		
		Metabolic disorders	↑	o	-	o	o	o
		Respiratory diseases	↑	++	o	+	-	o
		Fertility disorders	↑					
		Injuries and integument damage	↑	++	-	+	- -	+
		Thermal comfort	↑	+	o	+	+	++
		Heat stress	↑	+	- -	o	-	++
		Cold stress	↑	o	++	++	++	++
		Air quality	↑	++	o	+	o	+
		Comfort when resting, feeding and walking	↑	++	- -	o	- -	o
		Lying areas	↑	++	-	o	- -	+
		Feeding place	↑	++	- -	-	- -	- -
		Walkway	↑	++	- -	o	- -	o
		Ease of movement	↑	++	-	+	- -	-
		Slip resistance	↑	++	-	+	-	+
		Available space	↑	++	-	+	- -	-
		Expression of social and natural behaviors	↑	++	-	o	- -	-
		Herd stability and competition	↑	++	o	o	-	-
		Pasture access	↑	++	- -	o	- -	-
		Positive emotional state	↑	++	-	+	- -	o
		Technical and weather-related risks	↑	+	o	o	o	o
		Safety from predators and parasites	↑	-	++	++	++	++
		Protection from predators	↑	- -	++	++	++	++
		Safety from parasites	↑	-	++	+	++	++

	Transportation		**Stress due to capture, restraint and transportation**	←	+	o	o	o	o
		Slaughter	**Stress and suffering during the slaughter process**	←	++	- -	- -	- -	- -
			Calm and familiar surroundings	←	++	- -	- -	- -	- -
			Stress-free stunning/killing method	←	++	- -	- -	- -	- -
			Susceptibility to errors	←	o	-	-	-	-
Ecology	Water		**Freshwater utilization**	←	+	o	o	o	o
			Eutrophication	←	+	o	o	o	o
	Air		**Global warming due to greenhouse gases**	←	+	o	o	o	o
			Fossil energy use	←	+	o	o	o	o
			Methane emissions	←	-	+	o	o	o
	Soil		**Soil degradation**	←	++	-	o	-	-
			Carbon storage	←	++	-	o	-	-
			Erosion	←	++	-	o	-	-
			Acidification	←	++	o	o	-	-
			Compaction	←	+	-	-	-	-
		Biodiversity	**Land demand**	←	+	+	+	+	+
			Arable land requirement	←	++	-	o	-	-
			Agricultural land requirement	←	-	++	+	++	++
			Biodiversity	←	++	o	o	o	o
			Biodiverse flora	←	++	o	o	o	o
			Biodiverse fauna	←	++	o	+	o	o
Economy	Profitability		**Capital intensity**	←	++	o	-	o	-
			Production output	←	- -	++	+	++	++
			Price stability and autonomy	←	++	-	o	-	-
			Workload	←	o	+	o	++	-
			Standardization and automation	←	- -	++	++	++	o
			Bureaucratic burden	→	-	+	+	+	+
	Security		**Legal security**	→	-	+	+	+	+
			Political security	→	o	-	+	-	+
			Sales reliability	→	+	-	+	-	+
			Market access restrictions	→	- -	+	-	+	-
			Price formation	→	- -	+	-	+	-

Legend: Effect on criterion/indicators (←) / Influence of criterion/indicators on system (→)	
++	Positive (corresponds to the target direction of the indicator)
+	More positive
o	Neutral
-	More negative
- -	Negative
	Not specified / mixed opinion

Note: A system can have an influence on the respective sustainability criteria (←).However, it is preferred or discriminated against by the supersystem, i.e. it does not change the supersystem (→). This is indicated by the direction.

Production potential

The calculated potential of meat and milk production from multifunctional animal husbandry is between 644.2-1030.0 thousand tons of saleable beef (Figure 5) and 18.6-29.6 million tons of milk (Figure 6). In the lowest scenario, this corresponds to 220.4 kg milk/a (603.9 g/d) and 7.7 kg/a (21.0 g/d) meat per person. In Germany, the recommended requirement in 2022 according to the German Nutrition Society (DGE) was exceeded by 47% for milk and 121% for all meat.

According to new recommendations, which include health aspects, environmental factors and usual consumption habits (Schäfer et al. 2024), the consumption of milk is even increased by 94% and meat by 223%. Under the assumptions made, the minimum scenario would already cover 91-121% of milk consumption and 32-49% of meat consumption, or 77% of beef consumption. In the case of milk and beef, there is the potential to satisfy current consumption.

Even without drained peatlands (20.5% of grassland and 2.8% of cropland according to DEHSt 2023), at least 191.3 kg milk/a (524.2 g/d) and 6.7 kg/a (18.2 g/d) meat per person would still be available. This would result in a 13% reduction if full rewetting were implemented as a climate protection measure, without the management of peatlands by specific cattle breeds (e.g., Highland cattle) or water buffalo.

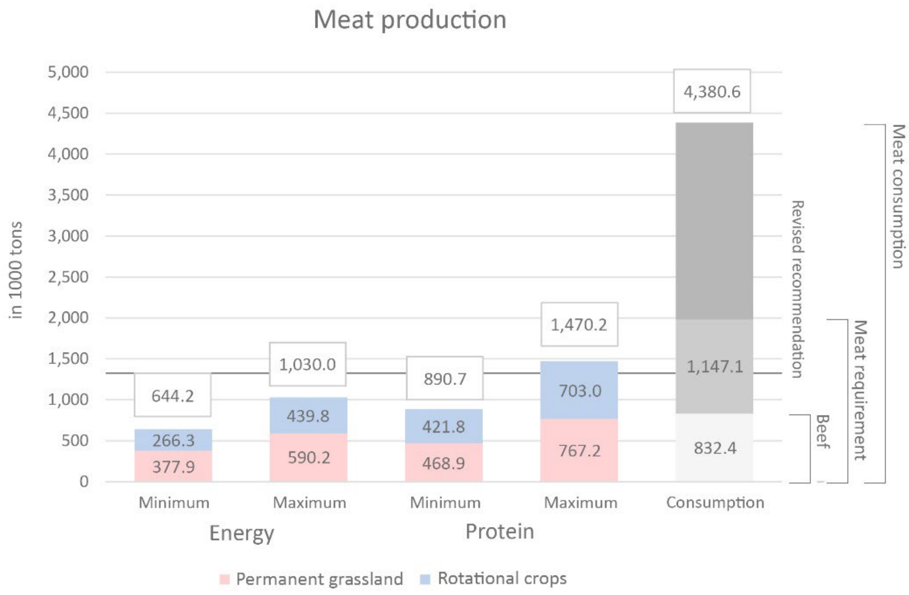

Figure 5: Potential of annual beef production in Germany compared to demand according to DGE and consumption in 2022 (requirement according to Breidenassel et al. 2022, new recommendation according to DGE 2024 and consumption according to BLE 2023d)

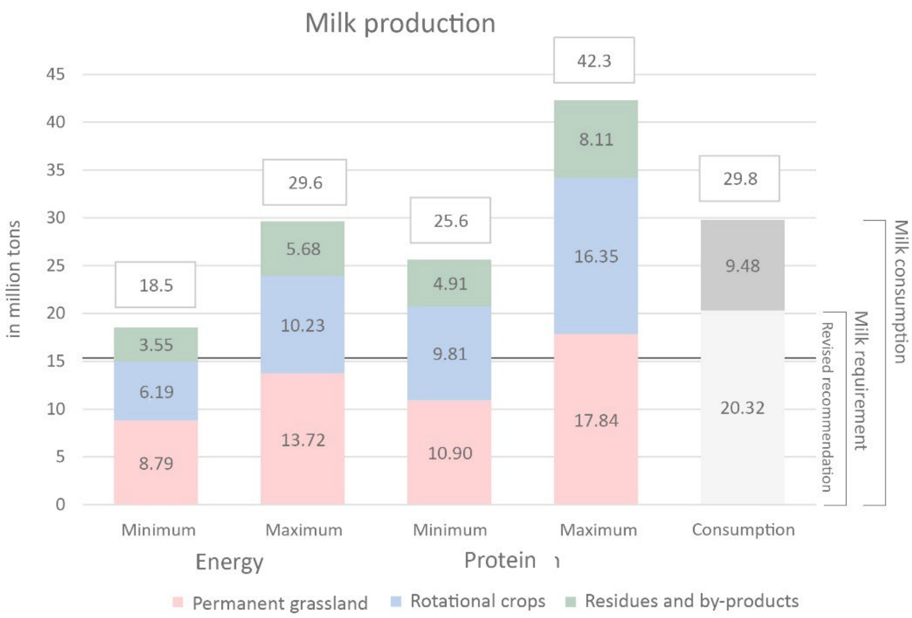

Figure 6: Potential of annual milk production in Germany compared to nutritional requirements according to DGE and consumption in 2022 (requirements according to Breidenassel et al. 2022, new recommendation according to DGE 2024 and consumption according to MVI 2023)

Calf feeding

A longer supply of calves with whole milk over 5 months with 900 kg milk consumption reduces the saleable milk volume by 11.2 % to 536.3-857.4 g/d/head (195.7-313.0 kg/a/head) or 16.46-26.31 million tons per year.

Cattle population

The possible cattle population in the calculated scenarios is between 10.4-16.6 million with 4.0-6.4 million dairy cows (see Figure 7) with 2.1-3.3 LU per hectare of permanent grassland. The lower level is at a comparable level to the current stock (-5 %) with 6 % more dairy cows. At the higher level, 52-69 % more cattle or dairy cows can be kept.

Historically, the calculated maximum number of cattle was exceeded until the 1940s (World War II) and between 1968-1991. The maximum dairy cattle population was only undercut after reunification.

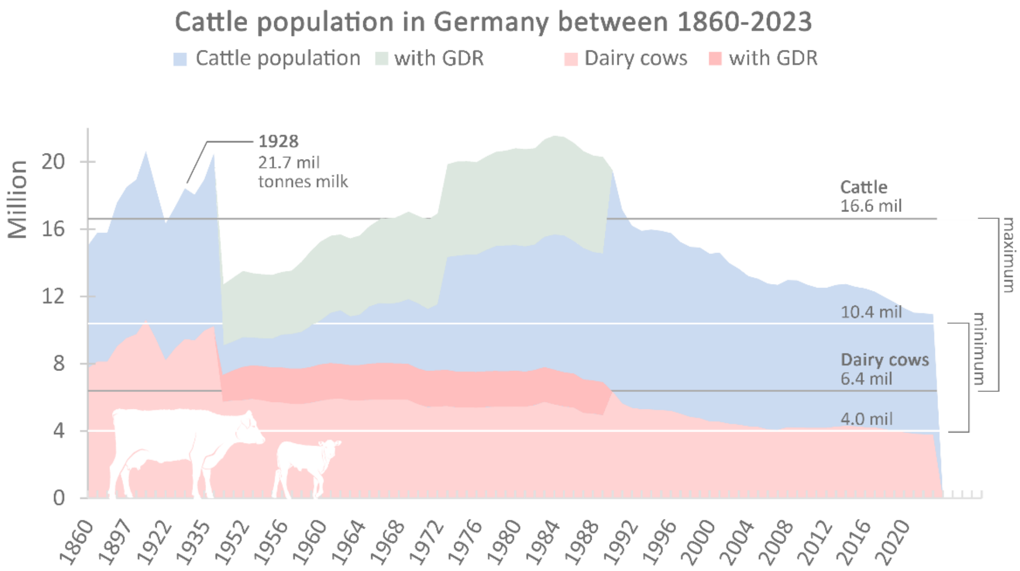

Figure 7: Cattle and dairy cattle population in Germany (German Empire) between 1860-2023 in millions without correction for the available larger agricultural area in the German Empire (data from Statistisches Reichsamt 1930 (1897-1937), Statistisches Bundesamt 2023 and Statistisches Amt der DDR 1990 (1955-1990))

4 | DISCUSSION

Multifunctional animal husbandry is a physiocentric system that places the functions of the animals at the center of sustainability considerations. This is a fundamental difference to other sustainability models. A high level of animal welfare is a necessary condition for the unrestricted performance of the various functions. This includes a largely natural husbandry environment for the animals. In principle, a high degree of multi-functionality could serve as a simple proxy for the sustainability of a system. This was also indicated in the system comparison, in which the sustainability values increase with growing multifunctionality.

The assumptions made show that the multifunctional livestock system could be superior to the current system and possible improved husbandry systems from a sustainable perspective. The MAH is fully integrated into a circular economy, as no feed is used that competes with humans for food. It also complies with animal welfare and constitutional law as well as societal expectations of sustainable livestock farming (see WBA 2015) and the inert moral understanding of humans. Unlike the majority of conventional systems, MAH fulfills these criteria.

Only from an economic point of view does MAH seem less advantageous due to the lower production volumes in today's market and pricing system. The land-based approach would also require the decentralization of processing structures such as dairies and slaughterhouses. Other site conditions such as the traffic situation and a lack of land in a certain area make implementation more difficult for farms. However, alternative housing systems that improve animal welfare are also associated with higher costs (Deblitz et al. 2021) or are not economically viable (BZL 2022). However, the barn models discussed today are mostly limited to housing. Numerous aspects, such as feeding with a high proportion of maize, which can pose an ecological and social problem, remain unchanged. The multidimensional perspective in MAH prevents this.

A value of over 60%, as achieved in the defined MAH, is proposed as the target value for the degree of multifunctionality, i.e. the relative fulfillment of the various possible functions.

Production potential in Germany

The current production volumes of meat and milk in Germany cannot be achieved in an MAH. However, the calculations of the production potential show that it could be possible to cover the nutritionally recommended milk and (beef) meat requirements according to the DGE through multifunctional animal husbandry. The available energy is the limiting factor, as more protein can be obtained from forage. The exact forage potential in Germany depends on a variety of conditions, including soil type and climate, in order to determine the quality and quantity of grassland growth and crops from crop rotations or for foodstuffs that produce by-products and residues. Simplified, the formula for determining the feed quantity is:

Feed potential = permanent grassland + non-edible organic matter

Non-edible biomass includes (1) by-products and residues from production and the food industry, (2) field fodder that is necessary in crop rotations to keep the fields healthy and cannot be replaced by arable crops that are edible for humans or alternative land use methods with net benefits for the food system such as biodiversity and climate measures, or (3) low-quality arable crops that are not yet used for human consumption (Figure 3). A large proportion of these feedstuffs are at least theoretically suitable for human consumption. However, this would require a change in consumption and eating behavior and possibly nutritional technology research.

Alternative uses of grassland

The conversion of grassland to arable land for direct human food production - as would theoretically be possible on around 0.7 billion hectares worldwide (Mottet et al. 2017) - cannot be recommended. A change in land use would, among other things, break down humus and release CO_2 and N compounds. From an ecological point of view, grassland use by cattle has advantages over arable land, for example in terms of soil protection, biodiversity or carbon storage (Beillouin et al. 2023; Borrelli et al. 2017; Modernel et al. 2013; Subak 1999; Hart 2001; Kun et al. 2021; Dierschke & Briemle 2002 according to BfN 2014).

The energetic use of non-edible biomass, which is advocated by supporters of livestock-free agriculture, cannot be recommended from a nutritional perspective either, as it means an indirect loss of food. Utilization for energy would reduce the amount of available feed. In waste hierarchies for the prevention of food waste, the production of animal feed is preferred over energy use - after exhausting all possibilities for direct use for human consumption (e.g. US EPA 2015 and EU 2016). The recycling sequence can be boldly described as "plate, trough and tank" and represents a consistency strategy in order to use the raw materials produced as sensibly and for as long as possible in line with the circular economy concept.

The increased competition for land due to the cultivation of energy crops also violates these principles, even if energy production from renewable raw materials such as oilseeds and grains results in by-products that can be used as animal feed.

Criticism of the current cultivation and use of feed grain and other arable crops used as animal feed is derived analogously from the utilization hierarchy. Among other things, the German Farmers' Association argues that many areas on which feed grains such as rye and barley are grown are not suitable for wheat cultivation in terms of climate or quality and that not all crops meet the quality requirements for direct human use (DBV 2022). Possible alternatives may concern (1) cultivation and (2) utilization.

(1) Cultivation

Some of the poor arable land could be used for alternative crops or for grassland use with carbon build-up and erosion protection compared to arable farming. If the production potential is too low, conversion into natural ecosystems could be achieved by afforestation and the creation of protected natural areas. A short-term loss of food could be argued, at least in the case of forests and natural areas, due to less available fodder, as no comparable hunting yield from game could be assumed.

The potential long-term benefits of these measures for the regional and global food system and food supply would have to be weighed against this - for example, through greater biodiversity with more pollinators or carbon storage for climate stabilization to prevent yield losses due to droughts and heavy rainfall. Alternative cultivation methods to large-scale arable farming could also be considered to create greater heterogeneity in the landscape and address potential sustainability issues without giving up land for food production.

(2) Utilization

The arable crops produced, such as malting barley or bread wheat, which do not meet the minimum quality requirements of the customer market in terms of brewing and baking quality and are currently used as animal feed, could be put to alternative use. For example, products such as flat bread could be produced that do not require high baking quality. This would require appropriate market structures for these products, which would have to meet an oversaturated market or be marketed abroad. In addition, there could be an increased switch to less demanding grains or crops such as rye, oats, buckwheat or other wheat varieties whose baking quality is less sensitive to lower protein levels (Saaten Union n.d.). For example, rye can be used to make bread, oats for oat flakes or muesli and buckwheat for groats.

The inelastic supply of agricultural production and the demand oligopoly of food retailers puts agriculture at the bottom of the market. Trade and/or industry would therefore have to create appropriate structures for alternative products made from lower-quality raw materials that would otherwise be used for animal feed. At the same time, a change in consumer and eating behavior is required. It can be assumed that more than 14% of animal feed (according to Mottet et al. 2017: 4) or arable land in use could be used for human nutrition if cultivation and utilization were to be changed. This figure gives a false impression of the efficiency of the current system.

In the end, the design depends on alternatives, political goals, scientifically sound assessments and financial and legal reviews, which would also have to be initiated by agricultural stakeholders, the food industry and food retailers from a sustainability and nutritional perspective in order to secure the food supply in the long term.

Ecological and economic dimensions

Livestock population, climate impact and land use

A constant to increasing number of cattle of 10.4-16.6 million in multifunctional animal husbandry is recommended for Germany from a nutritional perspective in order to exploit the production potential. The population size should be linked to the land and feed potential in order to establish an efficient nutrition system. This is in contrast to current calls for decreasing cattle numbers to mitigate climate change. However, such demands are often based on a one-dimensional view of GHG balances that do not consider biogenic emissions in the context of the natural carbon cycle.

Biogenic methane and CO_2 emissions are part of this cycle and are often misclassified in common CO_{2eq} footprints for animal products. Reducing these emissions by lowering livestock numbers or increasing efficiency could have a cooling effect in the short term (Liu et al. 2021; Allen et al. 2018), but could have negative consequences in the long term if this is accompanied by increased use of fossil energy. If the population remains the same, methane emissions from cattle will not contribute to further warming. The historical cattle population 100 years ago already exceeded the current population.

The benchmark for assessing greenhouse gases should be fossil fuels, which have a long-term impact on global warming through CO_2 (see Howarth 2014). Accordingly, reduction strategies should also start with anthropogenic fossil methane, which is used to generate energy and accounts for around a third of global CH4 (Hmiel et al. 2020). In addition, the production alternative to animal products from an MAH would have to be examined. Increased plant production, which would replace animal products, is also dependent on fossil energy today and requires arable land that releases carbon in the long term. Only grazing cattle, even in comparison to mowing grassland, theoretically requires no external energy during the vegetation period. However, the minimization of fossil energy use, especially for winter fodder production, should be promoted through more efficient technology.

Grazing adapted to the environment can not only preserve grassland with diverse ecosystem functions, but also lead to a negative CO_{2eq} balance, as grassland can act as a carbon sink (Wang et al. 2015; Liebig et al. 2010; National Trust 2012; Stanley et al. 2018). Over decades, such systems can sequester more carbon than they emit until a new equilibrium is reached, partly because the soil is better protected from erosion by year-round vegetation cover (Teague et al. 2016; Machmuller et al. 2015). Further improvements are possible through silvopastoral systems that also integrate trees (Gaitán et al. 2016).

The criticism of pasture feeding with regard to high land use overlooks the fact that many pasture areas cannot be used for direct human nutrition. The decisive criterion should be the proportion of arable land used for livestock production. In theory, higher land productivity could create more untouched natural space and reduce the risk of zoonosis by increasing the distance to wild animals (Hayek 2022). In reality, however, there is often a rebound effect with increasing production volumes and land expansion. In order to exploit the potential benefits of increasing efficiency for the natural environment, a production limit would have to be introduced - as exists in the MAH - and agricultural areas would have to be transformed into selected, natural ecosystems.

Efficiency and sustainability strategy

Modern agriculture is often described as efficient because it makes optimum use of resources per unit. However, this one-dimensional view neglects the overall use of resources and sufficiency aspects. Extensive systems such as pasture feeding show the highest conversion rate of plant proteins usable by humans into animal proteins and cover more functions, which in contrast to intensive systems leads to a positive overall protein balance (Mottet et al. 2017).

A combination of different strategies is needed to improve sustainability. The current efficiency strategy, which has led to a tripling of harvest volumes since 1928 (Statistisches Reichsamt 1930; Destatis n.d.), does not solve all human problems and can even be counterproductive due to the re-bound effect. Without natural or self-imposed scientific limits, a pure increase in efficiency could exceed the planetary boundaries faster than a less efficient system. The limits are therefore necessary to protect humanity and the long-term use of limited natural resources.

In livestock farming, the efficiency of concentrated feed used through breeding of high-performance breeds, which only leads to a relative reduction in arable feed, and possible energy savings through digitalization and mechanization must therefore be limited by capping consumption. The MAH implements this by using the nutritional requirements as the first limit (sufficiency strategy) and the sustainable production potential as the second limit. The consistency strategy is implemented through the correct utilization sequence (human nutrition, animal feed, energy use). The efficiency argument would therefore only be valid if the two limits were observed.

Nutritional aspects and global perspective

The discussion about animal products - and especially about necessary animal proteins - often neglects the lack of other important foods. According to DGE recommendations, too few vegetables, pulses, fruit, nuts, potatoes and wholegrain products are consumed in Germany (Breidenassel et al. 2022). A change in diet with fewer animal products could counteract this deficiency.

Even if it cannot be assumed that the individual product is harmful to health in the right quantity, a system that produces too much contributes to overconsumption. This is prevented in the MAH. Overconsumption causes further social problems. Although food security is not currently at risk in Germany - due in part to imports - practices in the domestic food system can, however, exacerbate food shortages in other nations, e.g. through the use of agricultural land abroad (Destatis

2020). This can lead to political and social upheavals, wars and refugee flows, which could have a negative impact on Europe and Germany.

The costs of these externalities are difficult to determine. Ultimately, they would have to be included in the prices of products that do not make a positive net contribution to the food system and consume edible products for humans.

From a global perspective, meat consumption is likely to increase further due to population growth and rising prosperity (OECD & FAO 2023). This demand should be met by more sustainable production methods. Countries and regions with high water availability and plenty of grassland, such as Germany, Ireland and New Zealand, are predestined for sustainable cattle and ruminant husbandry. Possible consequences for the climate and corresponding solutions must be considered in the long term and globally.

MAH offers an approach that takes these various aspects into account and strives for a balance between production, environmental protection and food security. However, it requires a change in production and consumption as well as adapted political and economic framework conditions.

Economic challenges and international competition

In Germany, the sole adaptation of environmental and animal welfare standards in the European single market would weaken competitiveness and cause billions in losses (Schmitz 2019). It would lead to regional relocations of production, which would likely exacerbate sustainability problems. However, even uniform EU standards in a liberalized agricultural market can lead to the migration of production sites out of the EU due to competition on the global market (Isermeyer & Schrader 2003). The costs of beef production in Europe are already around two to three times higher than in North and South America (Deblitz 2011).

Regardless of the system, the framework conditions for livestock farming must lead to prices that allow producers to survive economically. In the short term, extensive systems with lower outputs and/or higher costs are more affected. At the latest when fossil fuels become scarce, the fixed and variable costs in intensive systems are likely to increase due to higher prices for building materials, machinery, fertilizer or feed.

The implementation of MAH therefore requires not only national but also international efforts to adapt the legal and economic framework conditions. This is the only way to establish a system that is both ecologically sustainable and economically viable and can hold out against global competition.

Ethical dimension

In addition to ecological and economic aspects, multifunctional animal husbandry (MAH) also takes important ethical dimensions into account. These ethical considerations are fundamental to the design of a sustainable and socially acceptable livestock farming system.

Legal and ethical principles

The German Animal Welfare Act defines animals as protected fellow creatures to which no one may inflict pain, suffering or harm without reasonable cause (§1 TierSchG). It shows that the suffering of animals should be avoided by law. However, there is no objective threshold for what constitutes suffering and pain. The lack of a definition of a reasonable basis shows the normative nature and permissive character of these laws. This can be seen as a placeholder for the test of human's rationality and sense of morality and justice (Luy 2018). Consequently, the treatment of animals in German society could be seen as a reflection of society's morals, values and reason. The MAH aims to close this gap by considering animal welfare as an integral part of the system.

The vagueness of the wording can be a gateway to two problems: (1) due to a weak interpretation, it can allow avoidable animal suffering and (2) due to the subjectivity of the interpretation, it can allow arbitrary state action, for example by veterinary authorities with excessive husbandry requirements. This represents a potential risk for animals and farmers.

Principles for maximizing animal welfare

Two perspectives can be defined that can be used as justification for maximizing animal welfare: (1) an animal has an intrinsic moral value and (2) the animal must be protected in order to avoid negative consequences for humans and society. Possible negative consequences for humans and society, such as antibiotic resistance or zoonoses, were examined in greater depth in the sustainability criteria. Reason would strive to minimize these negative effects in order to safeguard human existence. The moral value of animals is more difficult to assess.

Moral value of animals

There are no moral reasons that place the totality of animals below that of humans, which are free of arbitrariness and religion. The species boundary is morally irrelevant and can be described under the term speciesism (cf. Luy 2018). This is shown by the fact that individual criteria such as intelligence, which leads to a cognitive superiority of the human species as a whole over other animal species, can cause individuals of the human species to fall below selected individuals of other animal species. This applies, for example, to humans within early childhood development and with mental limitations whose brain development is incomplete or impaired. The modern understanding of morality prohibits labeling these people as inferior or denying them intrinsic value or moral status. A consistent and consequent interpretation would therefore also attribute a moral value to an animal.

Proportionality test

Assuming that an animal has a moral value, the existence of this being may only be outweighed by the threat to one's own existence. In the MAH, the use of animals is examined under this aspect of proportionality. The primary legitimate reasons are the need to meet human nutritional requirements, which can be met by a plant-based diet (Melina et al. 2016), and to increase the overall efficiency of the food system when resources are scarce. Unlike the conventional system, MAH aims to maximize this efficiency without compromising animal welfare. The MAH is therefore ethically more advantageous due to its efficiency, reduction of negative effects and higher value attributed to the animal. The path of least harm could therefore mean not only reducing or avoiding animal products but also maximizing animal welfare through improved husbandry systems, management and slaughter processes.

Criticism of existing evaluation approaches

The internationally recognized Five Freedoms cannot close the legal and ethical gap. Complete avoidance of negative stimuli, including pain and discomfort, would deprive the animals of some of their natural behavior and necessitate continuous monitoring and increased medication. The MAH takes into account that negative stimuli can be part of genetically anchored behavioral mechanisms and that animal welfare also requires positive experiences (see Mellor 2016).

> "The more opportunities a husbandry system offers the animals to perform their normal behavior and the better their biological needs are met, the less likely it is that the welfare of the animals will be impaired."
>
> (Brade & Flachowsky 2007)

Economic aspects and ethical implications

The economic benefit as the sole criterion has already been restricted by the Federal Administrative Court in Germany, as shown by the ban on chick killing (BVerwG 2019). Similarly, unavoidable pain caused by the use of high-performance dairy breeds (see Bauer et al. 2021), for example, should not constitute a reasonable cause either.

Inconsistently, other avoidable pain is permitted under the German Animal Welfare Act (TierSchG) for economic reasons, as numerous procedures such as castration, dehorning and tail shortening show, even though, contrary to Section 5 (2) TierSchG, comparable procedures in humans would not be carried out without anaesthesia and there are (more) painless alternatives. This includes the husbandry system, breeding and the killing process, which are based on economics and not reason. The import of products with lower animal welfare standards is also still permitted in Germany.

According to the logic of utilitarianism, there should also be no rational justification if the killing - and the associated breeding and husbandry - of an animal causes greater harm to society than the benefits resulting from the animal products, e.g. through an increased risk of zoonosis, antibiotic resistance and malnutrition. It also represents an inconsistent interpretation of utilitarianism, as the exaggeration of the interests of the social majority in the human context would provide the basis for the discrimination of minorities. At the same time, the principle is violated in the human context when the majority of the world's population suffers from current dietary patterns and food insecurity is increased by excessive consumption of animal products - the global South suffers a shortage, the global North a surplus that causes health problems (Sun et al. 2021).

The minimization of suffering, which is a fundamental social maxim, should be extended to all living beings for reasons of consistency and impartiality in the absence of morally relevant distinctions (Kemmerer 2006). The Animal Welfare Act also fails to stipulate that a farm animal should be offered a positive return for the services it provides, instead of merely avoiding suffering and pain. Only then would humans' inert sense of morality and justice not be violated (cf. van Gall & Luy 2019; Luy 2018).

The dual role of humans as users and protectors of animals is insurmountable. MAH strives for a balance between human needs and animal welfare, considering long-term ecological and social consequences. The ethical considerations in MAH go beyond mere compliance with legal requirements. They aim for a system that reflects the moral values of society and is practical and efficient at the same time. By integrating ethical principles into all aspects of animal husbandry, the MAH strives for a sustainable and socially accepted form of livestock farming.

Practical implementation and animal welfare monitoring

Animal welfare indicators and evaluation

In addition to access to pasture to exercise natural and social behaviors that are beneficial to the emotional state, a reduction to a few selected animal welfare and disease indicators that provide a good overview of animal welfare-related problems seems possible. These include the mortality rate, fertility rate or calving rate, productive life, udder and hoof health as well as breed- and location-related performance parameters such as milk yield and, in the case of fattening cattle, daily weight gain. Animal-related indicators are preferable to management- or resource-related indicators (Brinkmann et al. 2020), also in order to do justice to possible specific breed, breeding, feeding and husbandry differences, as they reflect the actual effects on animal welfare. The aim is to create a system with healthy and resilient animals, not merely to meet and control theoretical guidelines.

Reducing bureaucracy to increase animal welfare

The demand for greater monitoring, documentation and veterinary care across the board can pose a cost problem for small, extensive farms in particular. In the current price and market system, the increased personnel and veterinary costs per head of cattle are less easily offset by the lower production volumes compared to intensive farming. A system with demonstrably healthier animals should be freed from additional bureaucracy. This could be realized through a networked database of farms, slaughterhouses, renderers and dairies. Simple treatments of defined disease patterns by experienced animal caretakers should be possible without additional veterinary checks as long as the objectively verifiable health values on the farm remain inconspicuous.

In the interests of animal welfare, the reduction in bureaucracy should also include a simplified, more cost-effective process for pasture slaughtering. The necessity of the live inspection by an official veterinarian should be reviewed, as possible animal welfare problems could also be documented during the carcass inspection.

Although pasture slaughter is preferable from an animal-specific perspective, further studies should consider the broad application of mobile slaughter with regard to animal welfare, food and occupational safety, waste management and public health (Hultgren 2018).

Government measures and alternatives

The MAH could be a more pragmatic approach to achieving sustainability goals than various government instruments such as nitrogen surplus levies, animal welfare levies or VAT increases for animal products (see Richter et al. 2023). It would be less bureaucratic and would address the causes rather than just the symptoms of a flawed system. When designing measures, it must be ensured that extensive farms are not disproportionately burdened, as they often already have higher production costs. This would be possible, for example, with a value-added tax increase for animal products or CO_{2eq} pricing through higher biogenic methane emissions per unit of product.

Limitations and future research

The calculated sustainability value provides a relative assessment of the systems examined. Due to the use of an ordinal scale, the data quality is limited, which makes it difficult to interpret the differences between the systems. Future research should develop a common assessment standard and collect more comprehensive operational data. This would allow an absolute assessment and make the differences between the systems quantifiable using metric data.

5 | CONCLUSION

Multifunctional animal husbandry (MAH) represents an innovative, holistic approach to solving the pressing problems of current livestock farming in the dimensions of society, ecology and animal ethics. It illustrates how closely the welfare of humans and animals are interlinked and that a fundamental paradigm shift in animal husbandry is both possible and necessary.

The comprehensive evaluation framework with 46 criteria proves that MAH is superior to conventional husbandry systems in almost all areas. It achieves a higher degree of multifunctionality (62-67%) compared to current forms of dairy cow husbandry (22-37%) and fattening cattle (21-28%) and combined systems (32-53%), particularly in the areas of animal welfare, ecology and society.

The potential analysis for Germany shows that an MAH could cover the nutritionally recommended demand for milk (220-965 g per day) and the current consumption of beef (147-235 g per week), despite lower overall production than in the current system. This underlines the need to reduce the consumption of animal products to a level that meets nutritional requirements. The feed potential is based on grassland, by-products and necessary rotational crops and does not include human-edible feed.

Ecologically, MAH offers considerable advantages through efficient grassland use, soil protection and biodiversity conservation. The carbon balance can even be negative through adapted pasture management, which underlines the potential to comply with planetary boundaries. The criticism of high land use is put into perspective, as many grazing areas would not be usable for direct human consumption.

> "Cattle appear to us today as the most indispensable of all domestic animals. It is useful to us both during its life and after its death in that it lends us its organism for the performance of work, provides us with a product of this organism in milk (and also in manure), and finally, after its death, allows us to utilize every part of its body."
>
> (Wilkens 1885 as cited in LfL 2006)

MAH complies with the Animal Welfare Act and does justice to the moral status of animals as sentient beings. It offers an approach that meets both ethical demands and legal requirements better than current systems.

However, the economic aspects represent a key challenge. Lower production volumes and necessary structural adjustments require innovative solutions and possibly political intervention in order to finance higher standards and create fair conditions for farmers.

The overarching goal is to achieve land-bound, cycle-oriented livestock farming that is geared towards animal welfare and makes the best possible use of natural functional potential. To this end, a degree of multifunctionality of over 60% and a focus on nutritional requirements is recommended as the upper production limit.

To ensure long-term sustainability, MAH combines efficiency, consistency and sufficiency strategies. This also includes adjustments to consumer behavior and market structures.

The study makes an important contribution to the debate on the future of livestock farming by quantifying the potential of an alternative system for the first time and proposing a holistic evaluation framework. It highlights the need for far-reaching systemic change that involves all stakeholders and must be supported by a broad social consensus.

There is a need for further research into practical implementation, the development of transformation paths and the investigation of regional conditions. A broad social discourse is necessary in order to examine the feasibility and develop concrete implementation steps.

FURTHER INFORMATION

Complete paper with technical appendix under https://orgprints.org/id/eprint/53237.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflicts of interest.

LITERATURE

Allen, Myles R., Shine, Keith P., Fuglestvedt, Jan S., Millar, Richard J., Cain, Michelle, Frame, David J. et al. (2018): „A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation" npj Climate and Atmospheric Science. (1)Nr. 1 (2018), 16. doi:10.1038/s41612-018-0026-8

Battaglia Richi, Evelyne, Baumer, Beatrice, Conrad, Beatrice, Darioli, Roger, Schmid, Alexandra und Keller, Ulrich (2015): „Health Risks Associated with Meat Consumption: A Review of Epidemiological Studies" International Journal for Vitamin and Nutrition Research. (85)Nr. 1–2 (2015), 70–78. doi:10.1024/0300-9831/a000224

Bauer, A, Martens, H und Thöne-Reineke, C (2021): „Tierschutzrelevante Zuchtprobleme beim Milchvieh – Interaktion zwischen dem Zuchtziel „Milchleistung" und dem vermehrten Auftreten von Produktionskrankheiten" Berliner und Münchener Tierärztliche Wochenschrift. Nr. Berliner und Münchener Tierärztliche Wochenschrift 134, 1-9 (2021), 1–9. doi:10.2376/1439-0299-2021-5

Beillouin, Damien, Corbeels, Marc, Demenois, Julien, Berre, David, Boyer, Annie, Fallot, Abigail et al. (2023): „A global meta-analysis of soil organic carbon in the Anthropocene" Nature Communications. (14)Nr. 1 (2023), 3700. . Nature Publishing Group doi:10.1038/s41467-023-39338-z

Bell 1997 nach Brade & Brade 2017a (keine vollständige Quellenangabe im Dokument vorhanden)

Benton, Tim G, Bieg, Carling, Harwatt, Helen, Pudasaini, Roshan und Wellesley, Laura (2021): „Food system impacts on biodiversity loss" (2021). https://www.chathamhouse.org/sites/default/files/2021-02/2021-02-03-food-system-biodiversity-loss-benton-et-al_0.pdf [07.04.2023].

BfN (2014): „Grünland-Report | BFN". https://www.bfn.de/publikationen/bfn-report/gruenland-report [27.10.2023].

BLE (2023d): Versorgung mit Fleisch in Deutschland im Kalenderjahr 2010-2022 (Neuberechnung). https://www.ble.de/DE/BZL/Daten-Berichte/Fleisch/fleisch_node.html [16.10.2023].

BMEL (2019): „Nutztierstrategie - Zukunftsfähige Tierhaltung in Deutschland" (2019). https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/Nutztierhaltungsstrategie.pdf?__blob=publicationFile&v=11 [04.03.2023].

Borrelli, Pasquale, Robinson, David A., Fleischer, Larissa R., Lugato, Emanuele, Ballabio, Cristiano, Alewell, Christine et al. (2017): „An assessment of the global impact of 21st century land use change on soil erosion" Nature Communications. (8)Nr. 1 (2017), 2013. doi:10.1038/s41467-017-02142-7

Brade & Brade 2007 (keine vollständige Quellenangabe im Dokument vorhanden)

Brade & Flachowsky 2007 (keine vollständige Quellenangabe im Dokument vorhanden)

Breidenassel, Christina, Schäfer, Anne Carolin, Melanie, Micka, Richter, Margrit, Linseisen, Jakob und Watzl, Bernhard (2022): „The Planetary Health Diet in contrast to the food-based dietary guidelines of the German Nutrition Society (DGE)" Ernahrungs Umschau. (69)Nr. 5 (2022), 56–72. doi:10.4455/eu.2022.012

Brinkmann, Jan, Cimer, Kornel, March, Solveig, Ivemeyer, Silvia, Pelzer, Andreas, Schultheiß, Ute et al. (2020): „Tierschutzindikatoren: Leitfaden für die Praxis – Rind" (2020). https://www.ktbl.de/fileadmin/user_upload/Allgemeines/Download/Tierwohl/Leitfaden2020_Milchkuehe.pdf [10.10.2023].

BVerwG (2019): Urteil vom 13.06.2019 - BVerwG 3 C 28.16 - Untersagung des Tötens männlicher Küken. Bundesverfassungsgericht https://www.bverwg.de/130619U3C28.16.0 [12.07.2023].

DBV (2022): Faktencheck Teller, Trog & Tank. https://www.bauernverband.de/fileadmin/user_upload/dbv/faktenchecks/Teller__Trog__Tank/Faktencheck_Teller_Trog_und_Tank_Final-komprimiert_neu.pdf [28.10.2023].

Deblitz, Claus (2011): „A new dimension for the analysis of the beef sector" (2011). https://literatur.thuenen.de/digbib_extern/dn054623.pdf [27.09.2023].

Deblitz, Claus, Efken, Josef, Banse, Martin, Isermeyer, Folkhard, Rohlmann, Christa, Tergast, Hauke et al. (2021): „Politikfolgenabschätzung zu den Empfehlungen des Kompetenznetzwerks Nutztierhaltung" (2021). https://literatur.thuenen.de/digbib_extern/dn063574.pdf [27.09.2023].

DEHSt (2023): „Moorschutz ist Klimaschutz". https://www.dehst.de/SharedDocs/downloads/DE/publikationen/factsheets/factsheet_Moore.pdf?__blob=publicationFile&v=9 [20.09.2024].

Destatis (2020): „Flächenbelegung" Statistisches Bundesamt. https://www.destatis.de/DE/Themen/Gesellschaft-

Umwelt/Umwelt/UGR/landwirtschaft-wald/Tabellen/flaechen-belegung.html [05.04.2023].

Destatis (2021a): „Stallhaltung, Weidehaltung - Landwirtschaftszählung - 2020" (2021). https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Produktionsmethoden/Publikationen/Downloads-Produktionsmethoden/stallhaltung-weidehaltung-tb-5411404209004.pdf?__blob=publicationFile [17.07.2023].

Destatis (2021b): „Tierhaltung: Dominierende Haltungsformen gewinnen weiter an Bedeutung" Statistisches Bundesamt. https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/08/PD21_N051_41.html [17.07.2023].

Destatis (2022): „Dauergrünland nach Art der Nutzung im Zeitvergleich" Statistisches Bundesamt. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Feldfruechte-Gruenland/Tabellen/zeitreihe-dauergruenland-nach-nutzung.html [15.10.2023].

Destatis (2023): Viehbestand. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Tiere-Tierische-Erzeugung/Publikationen/Downloads-Tiere-und-tierische-Erzeugung/viehbestand-2030410225324.pdf?__blob=publicationFile [17.07.2023].

Destatis (o. J.): „Anbauflächen, Hektarerträge und Erntemengen ausgewählter Anbaukulturen im Zeitvergleich" Statistisches Bundesamt. https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Feldfruechte-Gruenland/Tabellen/liste-feldfruechte-zeitreihe.html [28.10.2023].

DLQ (2022): „DLQ-Richtlinie 2.1- Tierwohl in der Milchviehhaltung mit System" (2022). https://infothek.q-check.org/wp-content/uploads/2020/06/DLQ-Richtlinie2.1.pdf [10.11.2023].

ECDC, EFSA, und EMA (2021): Antimicrobial consumption and resistance in bacteria from humans and animals : third joint interagency report on integrated analysis of antimicrobial agent consumption and occurrence of antimicrobial resistance in bacteria from humans and food-producing animals in the EU/EEA : JIACRA III 2016–2018. LU: European Centre for Disease Prevention and Control, European Food Safety Authority und European Medicines Agency. https://data.europa.eu/doi/10.2900/056892 [24.08.2023].

EU (2016): Bekämpfung der Lebensmittelverschwendung : eine Chance für die EU, die Ressourceneffizienz der Lebensmittelversorgungskette zu verbessern. Sonderbericht Nr. 34, 2016. Reihe: Sonderbericht Nr. ... (Europäischer Rechnungshof. Internet). LU: Publications Office. https://data.europa.eu/doi/10.2865/342949 [28.10.2023].

FAOSTAT (24.03.2023): „Crops and livestock products". https://www.fao.org/faostat/en/#data [07.04.2023].

Gaitán, Lucía, Läderach, Peter, Graefe, Sophie, Rao, Idupulapati und Van Der Hoek, Rein (2016): „Climate-Smart Livestock Systems: An Assessment of Carbon Stocks and GHG Emissions in Nicaragua" (P. Pardha-Saradhi, Hrsg.)PLOS ONE. (11)Nr. 12 (2016), e0167949. doi:10.1371/journal.pone.0167949

Greiner, Alexander (2023): „Eine multifunktionale Nutztierhaltung als Zukunftskonzept – Kriterien zur Bewertung und Konzipierung einer nachhaltigen Nutztierhaltung mit Fokus Rind“. https://orgprints.org/id/eprint/53237/ [27.06.2024].

Hart, Richard H (2001): „Plant biodiversity on shortgrass steppe after 55 years of zero, light, moderate, or heavy cattle grazing" (2001). https://www.ars.usda.gov/ARSUserFiles/30180000/Hart/25.%20Hart%202001.pdf [29.08.2023].

Hayek, Matthew N. (2022): „The infectious disease trap of animal agriculture" Science Advances. (8)Nr. 44 (2022), eadd6681. doi:10.1126/sciadv.add6681

Hmiel, Benjamin, Petrenko, V. V., Dyonisius, M. N., Buizert, C., Smith, A. M., Place, P. F. et al. (2020): „Preindustrial 14CH4 indicates greater anthropogenic fossil CH4 emissions" Nature. (578)Nr. 7795 (2020), 409–412. doi:10.1038/s41586-020-1991-8

Howarth, Robert W. (2014): „A bridge to nowhere: methane emissions and the greenhouse gas footprint of natural gas" Energy Science & Engineering. (2)Nr. 2 (2014), 47–60. doi:10.1002/ese3.35

Hultgren, J (2018): „Is livestock transport a necessary practice? Mobile slaughter and on-farm stunning and killing before transport to slaughter." CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. (13) (2018). doi:10.1079/PAVSNNR201813054

Isermeyer, Folkhard und Schrader, Lars (2003): „Politik : wer bezahlt den Tierschutz?" (2003). https://literatur.thuenen.de/digbib_extern/zi031995.pdf [13.07.2023].

Jungmichel, Norbert, Nill, Moritz und Wick, Kordula (2020): „Von der Welt auf den Teller: Kurzstudie zur globalen Umweltinanspruchnahme unseres Lebensmittelkonsums" (2020).

Kemmerer, Lisa (2006): In search of consistency: ethics and animals. Reihe: Human-animal studies. Leiden: Brill.

Kranert, M., Hafner, G., Barabosz, J., Schuller, H., Leverenz, D. und Kölbig, A. (2012): Ermittlung der weggeworfenen Lebensmittelmengen und Vorschläge zur Verminderung der Wegwerfrate bei Lebensmitteln in Deutschland. https://www.bmel.de/SharedDocs/Downloads/DE/_Ernaehrung/Lebensmittelverschwendung/Studie_Lebensmittelabfaelle_Langfassung.pdf?__blob=publicationFile&v=3

Kun, Róbert, Babai, Dániel, Csathó, András István, Vadász, Csaba, Kálmán, Nikoletta, Máté, András et al. (2021): „Simplicity or complexity? Important aspects of high nature value grassland management in nature conservation" Biodiversity and Conservation. (30)Nr. 12 (2021), 3563–3583. doi:10.1007/s10531-021-02262-z

LfL (2006): Aspekte zur Nachhaltigkeit in der tierischen Erzeugung. https://www.lfl.bayern.de/mam/cms07/publikationen/daten/schriftenreihe/p_19789.pdf [02.03.2023].

LfL (2021): „Gruber Tabelle zur Fütterung der Milchkühe, Zuchtrinder, Schafe und Ziegen". https://www.lfl.bayern.de/mam/cms07/publikationen/daten/informationen/gruber_tabelle_fuetterung_milchkuehe_zuchtrinder_schafe_ziegen_lfl-information.pdf [10.09.2023].

LfL (2023): „Gruber Tabelle zur Fütterung in der Rindermast". https://www.lfl.bayern.de/mam/cms07/publikationen/daten/informationen/gruber_tabelle_rindermast-2023_lfl-information.pdf [10.09.2023].

Liebig, M. A., Gross, J. R., Kronberg, S. L., Phillips, R. L. und Hanson, J. D. (2010): „Grazing management contributions to net global warming potential: a long-term evaluation in the Northern Great Plains" Journal of Environmental Quality. (39)Nr. 3 (2010), 799–809. doi:10.2134/jeq2009.0272

Liu, Shule, Proudman, Joe und Mitloehner, Frank M. (2021): „Rethinking methane from animal agriculture" CABI Agriculture and Bioscience. (2)Nr. 1 (2021), 22. doi:10.1186/s43170-021-00041-y

Liverani, Marco, Waage, Jeff, Barnett, Tony, Pfeiffer, Dirk U., Rushton, Jonathan, Rudge, James W. et al. (2013): „Understanding and Managing Zoonotic Risk in the New Livestock Industries" Environmental Health Perspectives. (121)Nr. 8 (2013), 873–877. doi:10.1289/ehp.1206001

Luy, Jörg (2018): Der faire Deal Basis eines neuen Rechtsverständnisses im Tier-, Natur- und Umweltschutz. (1. Auflage.). Baden-Baden: Nomos Verlagsgesellschaft mbH & Co. KG.

Machmuller, Megan B., Kramer, Marc G., Cyle, Taylor K., Hill, Nick, Hancock, Dennis und Thompson, Aaron (2015): „Emerging land use practices rapidly increase soil organic matter" Nature Communications. (6)Nr. 1 (2015), 6995. . Nature Publishing Group doi:10.1038/ncomms7995

Melina, Vesanto, Craig, Winston und Levin, Susan (2016): „Position of the Academy of Nutrition and Dietetics: Vegetarian Diets" Journal of the Academy of Nutrition and Dietetics. (116)Nr. 12 (2016), 1970–1980. doi:10.1016/j.jand.2016.09.025

Mellor, David (2016): „Updating Animal Welfare Thinking: Moving beyond the "Five Freedoms" towards "A Life Worth Living"" Animals. (6)Nr. 3 (2016), 21. doi:10.3390/ani6030021

Modernel, P, Astigarraga, L und Picasso, V (2013): „Global versus local environmental impacts of grazing and confined beef production systems" Environmental Research Letters. (8)Nr. 3 (2013), 035052. doi:10.1088/1748-9326/8/3/035052

Mottet, Anne, de Haan, Cees, Falcucci, Alessandra, Tempio, Giuseppe, Opio, Carolyn und Gerber, Pierre (2017): „Livestock: On our plates or eating at our table? A new analysis of the feed/food debate" Global Food Security. (14) (2017), 1–8. doi:10.1016/j.gfs.2017.01.001

Müller-Lindenlauf, Maria, Cornelius, Christine, Gärtner, Sven, Reinhardt, Guido, Rettenmaier, Nils und Schmidt, Tobias (2014): „Umweltbilanz von Milch und Milcherzeugnissen" ifeu. (2014). https://www.ifeu.de/fileadmin/uploads/IFEU-VDM-Milchbericht-2014.pdf [21.10.2023].

MVI (2023): „Geschäftsbericht 2022/23". https://milchindustrie.de/geschaeftsberichte/2022-2023/#98 [14.10.2023].

National Trust (2012): What's your beef? http://kinnebrookfarm.com/wp-content/uploads/2014/01/whatsyourbeef.pdf [05.09.2023].

OECD (2001): „Multifunktionalität: Auf dem Weg zu einem analytischen Rahmen" Nr. Zusammenfassung (2001). https://www.oecd-ilibrary.org/docserver/9789264192171-sum-de.pdf?expires=1681376131&id=id&accname=guest&checksum=14626F9C1E984AF80A689515FC689809 [13.04.2023].

OECD und Food and Agriculture Organization of the United Nations (2023): OECD-FAO Agricultural Outlook 2023-2032. OECD. doi:10.1787/08801ab7-en

Putfarken, Dorothee, Dengler, Jürgen, Lehmann, Stephan und Härdtle, Werner (2008): „Site use of grazing cattle and sheep in a large-scale pasture landscape: A GPS/GIS assessment" Applied Animal Behaviour Science. (111)Nr. 1–2 (2008), 54–67. doi:10.1016/j.applanim.2007.05.012

Reinhardt, Viktor und Reinhardt, Annie (1981): „Cohesive Relationships in a Cattle Herd (Bos Indicus)" Behaviour. (77)Nr. 3 (1981), 121–150. doi:10.1163/156853981X00194

Richter, Dr Beate, Zerzawy, Florian, Giesen, Henning und Grahl, Vinzenz (2023): „Maßnahmen und Instrumente zur Förderung einer nachhaltigen Milcherzeugung" (2023). https://foes.de/publikationen/2023_08_Greenpeace_Studie_Foerderung_nachhaltiger_Milcherzeugung.pdf [30.10.2023].

Saaten Union (o. J.): „Qualitätsweizen – Wie mit niedrigen Proteinwerten umgehen?" www.saaten-union.de. https://www.saaten-union.de/ [14.10.2023].

Schader, Christian, Muller, Adrian, Scialabba, Nadia El-Hage, Hecht, Judith, Isensee, Anne, Erb, Karl-Heinz et al. (2015): „Impacts of feeding less food-competing feedstuffs to livestock on global food system sustainability" Journal of The Royal Society Interface. (12)Nr. 113 (2015), 20150891. doi:10.1098/rsif.2015.0891

Schäfer, Anne Carolin, Boeing, Heiner, Conrad, Johanna, Watzl, Bernhard (2024): „Wissenschaftliche Grundlagen der lebensmittelbezogenen Ernährungsempfehlungen für Deutschland. https://www.ernaehrungs-umschau.de/fileadmin/Ernaehrungs-Umschau/pdfs/pdf_2024/03_24/EU03_2024_M158_M166_Online.pdf [28.09.2023].

Schmitz, P Michael (2019): „Globale Auswirkungen einer rein pflanzlichen Ernährung" (2019). https://www.ngw-landesverband.de/templates/images/news/556_2.pdf [10.09.2023].

SMUL (2008): Fruchtfolgegrundsätze im Ökologischen Landbau. Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie. https://publikationen.sachsen.de/bdb/ [21.10.2023].

Song, Mingyang, Fung, Teresa T., Hu, Frank B., Willett, Walter C., Longo, Valter D., Chan, Andrew T. et al. (2016): „Association of Animal and Plant Protein Intake With All-Cause and Cause-Specific Mortality" JAMA Internal Medicine. (176)Nr. 10 (2016), 1453. doi:10.1001/jamainternmed.2016.4182

Stanley, Paige L., Rowntree, Jason E., Beede, David K., DeLonge, Marcia S. und Hamm, Michael W. (2018): „Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems" Agricultural Systems. (162) (2018), 249–258. doi:10.1016/j.agsy.2018.02.003

Statistisches Reichsamt (1930): Statistisches Jahrbuch für das Deutsche Reich. https://resolver.sub.uni-goettingen.de/purl?PPN514401303_1930 [23.10.2023].

Steinfeld, Henning, Gerber, Pierre, Wassenaar, T. D., Castel, Vincent, Rosales M., Mauricio und Haan, Cees de (2006): Livestock's long shadow: environmental issues and options. Rome: Food and Agriculture Organization of the United Nations.

Subak, Susan (1999): „Global environmental costs of beef production" Ecological Economics. (30)Nr. 1 (1999), 79–91. doi:10.1016/S0921-8009(98)00100-1

Sun, Yangbo, Liu, Buyun, Snetselaar, Linda G., Wallace, Robert B., Shadyab, Aladdin H., Kroenke, Candyce H. et al. (2021): „Association of Major Dietary Protein Sources With All-Cause and Cause-Specific Mortality: Prospective Cohort Study" Journal of the American Heart Association. (10)Nr. 5 (2021), e015553. doi:10.1161/JAHA.119.015553

Teague, W.R., Apfelbaum, Steven, Lal, Rattan, Kreuter, Urs, Rowntree, Jason, Davies, C. et al. (2016): „The role of ruminants in reducing agriculture's carbon footprint in North America" Journal of Soil and Water Conservation. (71) (2016), 156–164. doi:10.2489/jswc.71.2.156

UBA (08.04.2022): „Veränderung der jahreszeitlichen Entwicklungsphasen bei Pflanzen“ Umweltbundesamt. . Umweltbundesamt. https://www.umweltbundesamt.de/daten/klima/veraenderung-der-jahreszeitlichen [12.09.2023].

UN (2022): World Population Prospects 2022. United Nations, Department of Economic and Social Affairs, Population Division. https://population.un.org/wpp/Download/Standard/Population/ [09.04.2023].

US EPA (12.08.2015): „Food Recovery Hierarchy" US EPA. https://19january2021snapshot.epa.gov/sustainable-management-food/food-recovery-hierarchy [28.10.2023].

van Boeckel, Thomas P., Glennon, Emma E., Chen, Dora, Gilbert, Marius, Robinson, Timothy P., Grenfell, Bryan T et al. (2017): „Reducing antimicrobial use in food animals" Science. (357)Nr. 6358 (2017), 1350–1352. . American Association for the Advancement of Science doi:10.1126/science.aao1495

van Gall, Philipp und Luy, Jörg (2019): Tierschutzkonform, aber unfair. https://www.tierethik.net/data/2019-02/TE_2019_2_Interview-GallLuy.pdf [12.07.2023].

van Zanten, Hannah H. E., Herrero, Mario, Van Hal, Ollie, Röös, Elin, Muller, Adrian, Garnett, Tara et al. (2018): „Defining a land boundary for sustainable livestock consumption" Global Change Biology. (24)Nr. 9 (2018), 4185–4194. doi:10.1111/gcb.14321

Wang, Tong, Teague, W. Richard, Park, Seong C. und Bevers, Stan (2015): „GHG Mitigation Potential of Different Grazing Strategies in the United States Southern Great Plains" Sustainability. (7)Nr. 10 (2015), 13500–13521. . Multidisciplinary Digital Publishing Institute doi:10.3390/su71013500

WBA (2015): Wege zu einer gesellschaftlich akzeptierten Nutztierhaltung. Gutachten. Wissenschaftlichen Beirats für Agrarpolitik beim Bundesministerium für Ernährung und Landwirtschaft. https://www.bmel.de/SharedDocs/Downloads/DE/_Ministerium/Beiraete/agrarpolitik/GutachtenNutztierhaltung.pdf?__blob=publicationFile&v=2 [03.03.2023].

Wilkinson, J.M. (2011): „Re-defining efficiency of feed use by livestock" Animal. (5)Nr. 7 (2011), 1014–1022. doi:10.1017/S175173111100005X

Wilkinson, J.M. und Lee, M.R.F. (2017): „Review: Use of human-edible animal feeds by ruminant livestock" Animal. (12)Nr. 8 (2017), 1735–1743. doi:10.1017/S175173111700218X

ANNEX

Grassland potential	Minimum scenario	Maximum scenario
Area	4,73 Mio. ha	
Management intensity	Extensive	50 % extensive, 50 % intensive
Cut utilization	2-3 cuts	3-4 cuts
Yield	55 dt DM/ha	82.71 dt DM/ha
Crude protein content	13.75 % in DM	15.0 % in DM
UDP content	15 %	
Energy content	5.9 MJ NEL/kg DM; 9.9 MJ ME/kg DM	6.2 MJ NEL/kg DM; 10.4 MJ ME/kg DM
Losses (harvest, storage, feed)	20 %	

Residue potential (Plant by-products and residues)	
Residuals included	– Oil cake, mill by-products, potato pulp, sugar beet pulp, sugar beet molasses, brewer's grains, malt germ, brewer's yeast – Quantity average accumulation in Germany between 2017/18 - 2021/22 – Energy and protein content values from Gruber table (LfL 2023)

Crop rotation potential		
Area	11.66 million ha	
Cultures included	50 % trefoil-grass, 50 % Alfalfa	
Scope of cultivation	1/5 of the arable land (annual cultivation in a five-part crop rotation) 82,7 dt DM/ha	1/3 of the arable land (two-year cultivation in six-part crop rotation)
Crude protein content	trefoil-grass: 20,8% in DM; Alfalfa: 13,8% in DM	
Energy content	trefoil-grass: 6,1 MJ NEL/kg DM; 10,2 MJ ME/kg DM Alfalfa: 5,44 MJ NEL/kg DM; 9,31 MJ ME/kg DM	
Losses (harvest, storage, feed)	20 %	

Feed requirement	
Dairy cattle	– Energy demand calculated via performance and maintenance requirement – Assumptions: 4,500 kg/year with 4.0 % fat and 3.4 % protein, 600 kg live weight – Demand: 3.3 MJ NEL/kg milk performance requirement and 35.5 MJ NEL/d maintenance requirement on 305 milking days = 84 MJ NEL/day – 60 MJ NEL/day set for early dry cows and preparers – Through concentrate and juice feed (1.38-2.21 kg DM/cow/d or 5.05-8.08 dt DM/cow/a) another 1,000 kg milk/year
Calves	– 800 g weight gain in month 2-5 with 35 MJ ME and 410 g nXP – 80 % weaning rate – 293 kg whole milk per calf for 2 months – Fattening of all calves
Fattening cattle	– 19 months Fattening after weaning at 5 months (150 kg) – 400 kg average live weight, 800 g daily weight gain – Demand: 81.9 MJ ME and 942 g XP
	Total requirement of calves and fattening cattle halved for annual requirement. Replacement of dairy cows included.

Demand with data from LfL 2021 and LfL 2023; area according to Destatis 2022

Milk potential	**Meat potential**
– Number of dairy cows multiplied by milk yield per cow – Deducting 293 kg milk/cow/year for calves – Deducting 1.25% milk losses along the value chain during processing (0.5%) and distribution to retail (0.75%) [1] – Intercalving period of 365 days as an ideal value – Calving rate of 90% – 5% stillbirths	– Half the number of fattening cattle multiplied by the final weight of 600 kg to obtain the weight of all animals slaughtered in a year – Dressing percentage of 53% assumed – Deduction of 4% due to possible animal losses – 70% as saleable quantity after deduction of liquid and cutting losses (meat waste) – Further deductions of 5.7% for losses due to storage (0.7%) and processing and packaging (5%) [2] – Residual materials only used to compensate for possible energy and protein deficits and seen as a reserve

Average consumption per capita calculated on the basis of the 2011 census (reference date 30.06.2022)
[1] Müller-Lindenlauf et al. 2014
[2] Kranert et al. 2012

Formulas

Dairy herd

$$X = \frac{Y}{K_1 + A * 2 * K_2}$$

X = Number of dairy cattle
Y = Available energy/protein
A = Weaning rate (calving rate minus calf deaths and stillbirths)
K_1 = Demand coefficient of dairy cattle
K_2 = Demand coefficient of fattening cattle, calves and herd replacement

The fattening herd is twice the dairy herd multiplied by the weaner rate (including stillbirths).

Saleable milk volume

$$VM = \left[X * M * AR - \left(K * X * AR * (1-T)\right)\right] * (1 - V)$$

VM = Saleable milk volume
X = Number of dairy cattle
M = Milk volume per cow and year
AR = Calving rate
K = Milk requirement per calf
T = Stillbirth rate
V = Losses along the value chain

Saleable quantity of meat

$$VF = \frac{N * L * G}{2} * (1 - T) * W * (1 - V)$$

VF = Saleable quantity of meat
N = Number of fattening cattle
L = Live weight (final weight)
G = Dressing percentage
T = Animal losses
W = Proportion of saleable goods in carcass weight
V = Losses along the value chain