

Review

Potentials of Grassland-Based Livestock Farming in Switzerland—A Scenario Comparison

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Abstract: As roughage consumers, ruminants have the unique ability to convert raw materials that are otherwise inedible for humans into valuable food products, thereby making them crucial to Swiss agriculture, particularly in mountainous regions. This article reviews the current state of grassland-based livestock farming in Switzerland and provides an overview of several studies that explore potential future scenarios for livestock production, along with their projected impacts. The scenarios discussed illustrate how grassland-based livestock systems could serve as a viable alternative for promoting more sustainable livestock production in the future. All of the studies examined justify grassland-based farming within the framework of a “feed-no-food” strategy, in which arable land is prioritized for human food production. This approach has several consequences: reduced availability of animal feed, fewer livestock, an increase in arable land for human food production, higher levels of plant-based food output, and enhanced self-sufficiency. However, these scenarios also call for a significant reduction in livestock production and consumption, which hinges on the willingness of society, the economy, and policymakers to embrace such changes.

Keywords: livestock; grassland-based livestock farming; scenarios



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1. Introduction

Swiss agriculture today is heavily characterized by livestock farming, particularly the rearing of ruminants. However, both globally and within Switzerland, livestock production and the consumption of animal products face increasing criticism due to their resource intensity and environmental impact [1–4].

The debate surrounding ruminant farming is polarized. On one side, critics highlight the significant environmental footprint of ruminant production, citing methane emissions from digestion and the high demand for water and land [4–6]. In contrast, proponents argue that ruminants play a key role in sustainable food systems, as they can convert inedible raw materials, such as roughage, into valuable food products [7–9]. This predominant or exclusive feeding of farm animals with meadow and pasture feed is referred to as grassland-based (livestock) farming [10].

In view of the conflicting goals identified through this discourse, a detailed consideration and weighing of this mode of production’s potential is necessary. In addition to assessing the current status of grassland-based livestock farming in Switzerland (Section 2), this article presents an overview of various studies that describe possible future scenarios for animal production in Switzerland and evaluate their impact (Section 3). In summary, the results show possible transformation paths for grassland-based livestock farming, as well as their risks and opportunities.

2. Grassland-Based Livestock Farming in Switzerland Today

Approximately 70% of Switzerland’s agricultural land is grassland, comprising both temporary meadows in the crop rotation and permanent meadows, as well as pastures [11].

This proportion is particularly high in the mountainous regions, where grassland far exceeds arable land (Figure 1). Including cultivation on arable land (mainly green maize), a total of about 74% of Switzerland's agricultural land is dedicated to roughage production. This allows nearly all the roughage required for domestic use to be produced within the country. Only 3% of roughage is imported, whereas the share of imported concentrated feed (including other types of feed) is significantly higher at 55% [11].

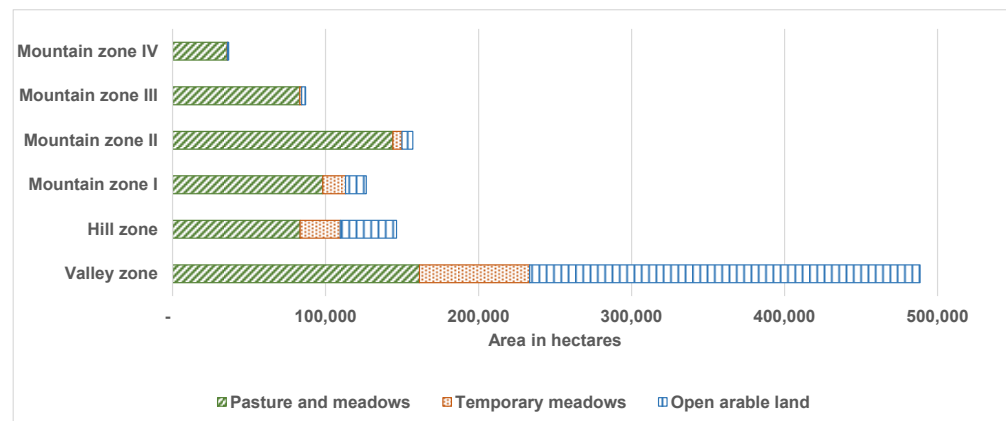


Figure 1. The share of agricultural land in different agricultural zones in Switzerland [11]. The subdivision of agricultural zones is based on climate, traffic situation, and surface design. The significance of ruminants in Swiss agriculture is evident in their substantial share of the national livestock population. Measured in livestock units, ruminants make up nearly 80% of the total population [11]. This is particularly important in mountainous regions, where extensive grasslands dominate the landscape. Most of Switzerland's sheep and goats, along with about 40% of its cattle, are raised in these mountain areas. In contrast, over 80% of poultry and pig production is concentrated in the lowland and hill zones.

Ruminant farming enables the productive use of grassland for food production. As such, grassland-based livestock farming makes a significant contribution to Switzerland's food supply. Domestic production fully meets the demand for milk and dairy products [11]. Additionally, Swiss ruminant farming provides approximately a quarter of the country's meat consumption [12] (Figure 2).

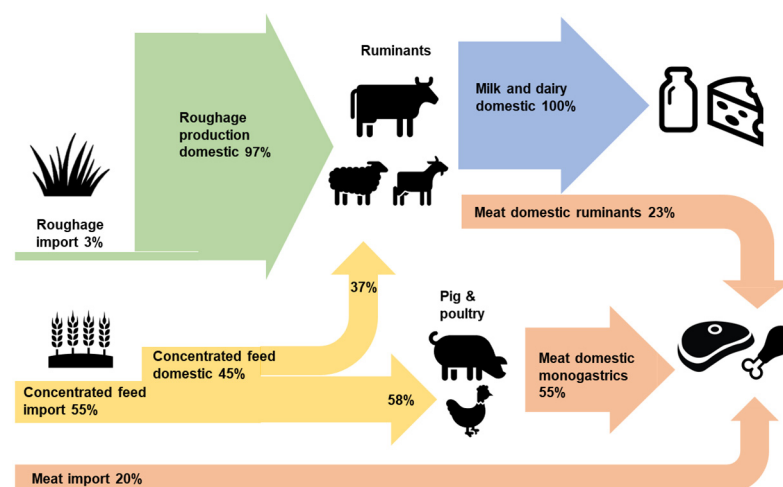


Figure 2. The distribution of the total feed quantities among Swiss livestock and its contribution to covering domestic consumption (differences arise from “other animals”, e.g., equidae; data related to weight dry matter; import corresponds to the trade balance; concentrated feed contains “other feed”); source: [11,12].

The data highlight both the current relevance and the specific challenges of grassland-based livestock farming in Switzerland. Given the country's topographical characteristics and the abundance of natural grasslands, ruminant farming is likely to remain important in the future. However, the question arises as to how this sector should evolve to align with a more sustainable food system. The following sections present the findings of various studies that explore this issue.

3. The Future of Grassland-Based Livestock Farming

For the comparison of future grassland-based livestock scenarios, studies were considered that deal either directly or indirectly with the use of grassland for livestock feeding in Switzerland. These are either (a) objectives and restrictions in the scenario, (b) a result of the modelling, or (c) a framework condition (use of all agricultural land). A total of 10 Swiss studies were identified for evaluation (Table 1).

3.1. Scenario Comparison

The studies can be divided into four categories. The first category comprises scenarios created using Agroscope's DSS-ESSA model system. This was originally developed to optimize agricultural production for Swiss food security for specific crisis scenarios such as yield or import losses [13]. Based on this, another model—Green DSS-ESSA—was created, which optimizes agricultural production with regard to environmentally friendly and resource-saving nutrition [14,15]. Grassland-based livestock farming is a result of the optimization in the model. By reducing domestic feed cultivation, high increases in domestic food production can be achieved. In both scenarios, the populations of monogastric animals decline sharply, while ruminant populations are only reduced by about a quarter. These differences are due to the use of grassland for feeding ruminants. An interesting addition is the “less grassland” scenario by von Ow et al. [14], as it allows the non-use of 70% of the existing grassland; in the other models, the use of all agricultural land is a requirement. The results show that optimizing resource conservation and nutrition would mean a significantly higher reduction in ruminant production to only 35% of the current production.

The second category includes modelling using Sol-m (Sustainability and Organic Livestock model) from the Research Institute of Organic Agriculture. The results of Stolze et al. [16,17] are essentially comparable to those in the first category. In addition, however, the results show that the use of the land freed up by the renunciation of concentrated feed cultivation influences the result of the modelling. The proportion of temporary meadows in crop rotation in particular has a strong influence on the availability of roughage. Without these meadows, the total production of beef and milk drops to about 50%.

Scenarios in the third category were created using Agroscope's SWISSland model system, which maps the supply and demand quantities of raw agricultural products in the Swiss agricultural sector. SWISSland was used to forecast the impact of the voluntary grassland-based milk and meat (GMF) program by the Swiss government [18,19]. The results show that the payments lead to a slight increase in the number of dairy cows, while at the same time decreasing production output.

The two studies in the fourth and last category [20,21] both explore the question of how many farm animals are needed in Switzerland to use the available grassland resources. Steller and Probst [21] calculate the number of animals that can be fed with today's meadows and pastures, including a temporary meadow share of 20%. Based on this calculation, today's production values of meat and milk can be maintained. Baur and Flückiger [20] came to a reduction in cattle numbers by about a quarter despite an increase in the proportion of temporary meadows in crop rotation to 40%. This can be attributed on the one hand to purely organic production methods and the associated lower yields in their scenario, as well as to an overall reduction in agricultural land. This reduction results from the creation of more areas for biodiversity, which primarily includes a conversion of existing meadows and pastures.

Table 1. A comparison of the scenarios for grassland-based livestock farming in Switzerland.

Study/Scenario	Land Use for Animal Production	Import of Animal Products and Feed	Feed Composition	Livestock (% of Current)	Production (% of Current)	
					Milk and Meat	Protein
Current situation (see Section 2)	60% of arable land for feed, 33% temporary meadows on arable land, 70% of agricultural land is grassland	55% concentrated feed import 7.3% livestock products import	75% roughage, 20% concentrate feed and 5% other feed	100%	100%	100%
Modelling using DSS-ESSA						
Zimmermann, Ferjani, et al. [13]: Modelling (DSS-ESSA) to assess the potential of the Swiss food supply from domestic production.						
DSS-ESSA	Optimised use of agricultural land, conversion of natural meadows (−6%) to arable land, temporary meadows on 22% of arable land, 80% less open arable land for fodder	No feed/livestock products import	Primarily roughage-based, low proportion of domestic concentrate production	Dairy cattle: 87% Pigs/poultry: 10%	Beef/veal: 83% Milk/dairy: 82%	Livestock: 49% Total: 72%
Zimmermann, Nemecek, et al. [15]: Green-DSS-ESSA is based on Zimmermann, Ferjani, et al. [13] but with a focus on minimizing environmental impacts.						
Green DSS-ESSA, Scenario Min ReCiPe	Use of all agricultural land, temporary meadows on 23% of arable land, extensification of natural meadow	2.8% of livestock products 11% of current feed import	Primarily roughage-based, low proportion of domestic concentrate production	Ruminants: 70% Cattle: 55% Pigs: 25% Poultry: 70% Total: 57%	Meat: 30% Milk/dairy: 144%	Total: 90%
Von Ow et al. [14]: Extending Green-DSS-ESSA to the scenario “less grassland”, in which grassland can be removed from the usable areas.						
Less grassland	Use of all arable land, 70% of grassland reduced	73% of current food import	S. Green DSS-ESSA	Ruminants: 35% Total: 32%	no info	
Modelling using SOL-M						
Stolze et al. [16]: Modelling of the impact of a nationwide implementation of regenerative milk and meat production by 2030.						
Regenerative Milk and Beef Production (RMF)	No cultivation of concentrated feed and silage maize for ruminants, freed-up arable land remains unused	No feed import for ruminants	In addition to roughage, only by-products as concentrated feed for ruminants	Cattle: 82%	Milk: 70% Beef: 80% Meat: 95%	Livestock: 78% Total: 81%
RMF + clover grass	See RMF, freed-up areas used for temporary meadows	Like RMF	Like RMF	Cattle: 96%	Milk: 82% Meat: 100%	Total: 90%
RMF + food instead of feed	See RMF, freed-up land used for food production (85%) and temporary meadow (15%)	Like RMF	Like RMF	Cattle: 88%	Milk: 75% Meat: 96%	Total: 89%
RMF incl. monogastric animal + food instead of feed	No cultivation of concentrated feed and silage maize for livestock (incl. monogastric animals), freed-up land used for food production (80%) and temporary meadow (20%)	No feed import (incl. monogastric animals)	Like RMF, the same applies to monogastric animals	Cattle: 90% Pigs: 20% Poultry: 26%	Milk: 76% Meat: 43%	Total: 84%
Stolze et al. [17]: Modelling of the impact of different food and agriculture scenarios, including feed-no-food, on health, environment, and economy.						
FeednoFood2050	No concentrated feed cultivation, current temporary meadow share	No feed/livestock products import	Roughage (ruminants) and by-products (monogastric animals)	no info	Beef: 80% Milk: 75% Poultry: 20% Pork: 70%	no info
FeednoFood2050 Temp2050	No concentrated feed cultivation, no temporary meadows in crop rotation	No feed/livestock products import	Roughage (ruminants) and by-products (monogastric animals)	no info	Beef: 50% Milk: about 45%	no info

Table 1. Cont.

Study/Scenario	Land Use for Animal Production	Import of Animal Products and Feed	Feed Composition	Livestock (% of Current)	Production (% of Current)	
					Milk and Meat	Protein
Modelling using SWISSland						
Mack et al. [18] and Mack and Kohler [19]: Modelling of the impact of GMF payments on production and price developments.						
GMF-Scenario 2025	Increase in grassland areas (1%), fewer extensive meadows and pastures	no info	Decrease in concentrates by 2.6%, increase in roughage by 2.2%	Dairy cows: 102%	Milk: 97%	no info
Other models						
Baur and Flückiger [20]: Calculation of the potential of grassland-based, organic agriculture with regard to milk and meat production.						
TOP-REF 2015	53% arable land for food, 39% temporary meadows, organic production, reduction in agricultural land by 24%	No import of animal feed	Primarily roughage-based, low domestic concentrate production, by-products	Total: 63% Cattle: 78% Pigs: 7% Poultry: 32%	Milk: 68% Meat: 35%	Milk: 68% Meat: 35%
TOP-Scenario 2050	54% arable land for food, 39% temporary meadows, organic production, reduction in agricultural land by 27%	No import of animal feed	Like TOP-REF 2015	Total: 61% Cattle: 76% Pigs: 5% Poultry: 32%	Milk: 66% Meat: 34%	no info
Stettler and Probst [21]: Calculation of the number of ruminants that could be fed with today's meadows and pastures.						
Optimal land use	Use of all agricultural land, 20% temporary meadows in crop rotation	No feed import	Domestic roughage and by-products	Cattle: 94% Pigs: 35%	Milk: 101% Beef: 98%	no info

The various scenarios show what grassland-based livestock farming in Switzerland could look like in the future and what changes would be associated with it in terms of livestock populations and production levels. In principle, it can be deduced from the results that the renunciation of concentrate cultivation and importation, while at the same time using existing grassland resources, only slightly reduces the production of milk and beef. This contrasts with pig and poultry production, which would experience a very strong decrease without the use of concentrated feed.

However, the question arises as to the extent to which the use of current grassland resources makes ecological sense. Both Baur and Flückiger [20] and von Ow et al. [14] show that a reduction in existing meadows and pastures would bring ecological benefits associated with a reduction in ruminant populations.

3.2. Impact of Grassland-Based Livestock Scenarios

3.2.1. Production and Nutrition

As can be seen in Table 1, a shift towards grassland-based farming leads to a reduction in livestock numbers and, consequently, a decrease in the production of animal products. This decline is most pronounced in pig and poultry production, primarily due to limitations in feed cultivation and imports. Depending on the scenario, the reduction in beef and dairy products ranges from 0% to 50%, driven by both a decrease in the availability of concentrated feed and, in some cases, reduced supplies of roughage.

The amount of roughage available is not only influenced by the extent of grassland area but also by the proportion of artificial meadows in crop rotations [16]. While the models generally produce comparable results, differences arise due to varying assumptions regarding production methods, projected yield increases, the impact of roughage-based diets on livestock productivity, and the overall availability of roughage.

It is important to highlight that in nearly all the scenarios discussed, Switzerland's theoretical self-sufficiency increases as arable land is redirected from animal feed production to the cultivation of plant-based foods. A degree of 100% self-sufficiency but with restricted

nutrition is achieved in the scenario of Zimmermann, Ferjani, et al. [13], which was created with the explicitly targeted function of complete self-sufficiency. In addition to reducing the cultivation of animal feed on arable land and animal populations, the goal of self-sufficiency also requires a change in diet. A contrasting effect on the degree of self-sufficiency can be seen in Baur and Flückiger [20]. The decline calculated here is due to the reduction in agricultural land and a shift to organic production, which leads to lower yields in both meat production and plant-based food.

Health effects are only discussed in Stolze et al. [17]. In comparison to the reference scenario, the Feed-no-Food2050 scenario, with reduced meat consumption and increased legume intake, shows a modest improvement in nutritional outcomes. However, another scenario explicitly aligned with the Swiss food pyramid demonstrates significantly better results in this regard.

3.2.2. Ecological Impact

The overall reduction in livestock and feed cultivation in the scenarios has positive ecological effects. In the Min ReCiPe scenario by Zimmermann, Nemecek, et al. [15], which was modelled with a view to minimizing environmental impacts, the overall environmental impact was more than halved compared to the reference scenario. It is important to note that the scenario involves various adjustments in the food system that go beyond a shift to grassland-based agriculture. However, the improved ecological impact is largely due to the abandonment of the cultivation and import of animal feed. The domestic land freed up allows more food to be produced and imports to be greatly reduced overall. The scenario requires the full use of agricultural land, including the existing grassland areas. In contrast, von Ow et al.'s [14] "less grassland" scenario allows grassland to be taken out of use to optimize environmental impacts. This can reduce the overall environmental impact by a further 10% through the resulting reduction in livestock populations.

Stolze et al. [16] compared different scenario variants of grassland-based farming, also with regard to their ecological impacts. The scenario "RMF incl. monogastric animals—food instead of feed" corresponds most closely to the idea of a completely grassland-based livestock system, as here, in contrast to the other scenarios, the renunciation of concentrated feed also applies to monogastric farm animals. As a result, in this scenario, the number of pigs and poultry decreases by about 80%, whereas the number of ruminants decreases by only 10%. For all scenarios, the environmental indicators examined (ammonia emissions, nitrogen surplus, phosphorus use, and greenhouse gas emissions) improve compared to the current situation. However, the scenario "RMF incl. monogastric food instead of food" performs best of all variants, which is due to the strong reduction in monogastric animals. Compared to those in the current situation, ammonia emissions can be reduced by 22%, nitrogen surpluses by 45%, phosphorus use by 26%, and greenhouse gas emissions by 14%.

A more comprehensive assessment of environmental impacts is provided by Stolze et al. [17], who compared their findings with a business-as-usual reference scenario. In the modelled Feed-no-Food2050 scenario (see Table 1), significant environmental improvements—both domestically and internationally—were achieved compared to the reference case. The total ecological footprint in Switzerland was reduced by nearly 13%, largely due to a substantial decrease in animal product consumption. Among the individual environmental indicators, greenhouse gas emissions in the Feed-no-Food2050 scenario were 25% lower, land use was 35% lower, biodiversity loss reduced by 13%, and eutrophication decreased by 24% compared to the reference scenario.

The TOP scenario [20] showed similar positive environmental impacts compared to the current situation. Greenhouse gas emissions are reduced by 30% and nitrogen surpluses by more than 50%. The scenario highlights also other positive outcomes, including the reduction in antibiotics used, the positive influence of agricultural extensification on biodiversity and the landscape, and improvements in animal welfare through pasture grazing, which is mandated for all livestock under the scenario.

In contrast to the extensification of grassland areas in Baur and Flückiger [20], the study by Mack et al. [18] shows that subsidies for grassland-based feeding can also lead to an intensification of grassland use and that extensively used grassland decreases in favour of more intensively used forms.

3.2.3. Socio-Economic Impact

The scenarios created with SWISSland [18,19] include economic modelling to evaluate the impact of the GMF (grassland-based milk and meat production) program on production and the economy. At farm level, positive income effects can be shown, which result from the payments and reduced feed costs. On the other hand, the modelling also shows that the feed-related decline in yield has a sectoral impact on the milk price and raises it. This price increase in turn has a positive effect on farmers' incomes.

Stolze et al. [17] highlight a potential side effect of the feed-no-food restriction: the profitability of products that generate “by-products” for animal feed could increase significantly, potentially driving up production.

As illustrated in the summary Figure 3, there are various ways in which a shift towards grassland-based farming systems could impact agriculture, the environment, nutrition, and the economy. Depending on the developments, these effects can be both positive and negative, necessitating a careful consideration in designing guiding measures.

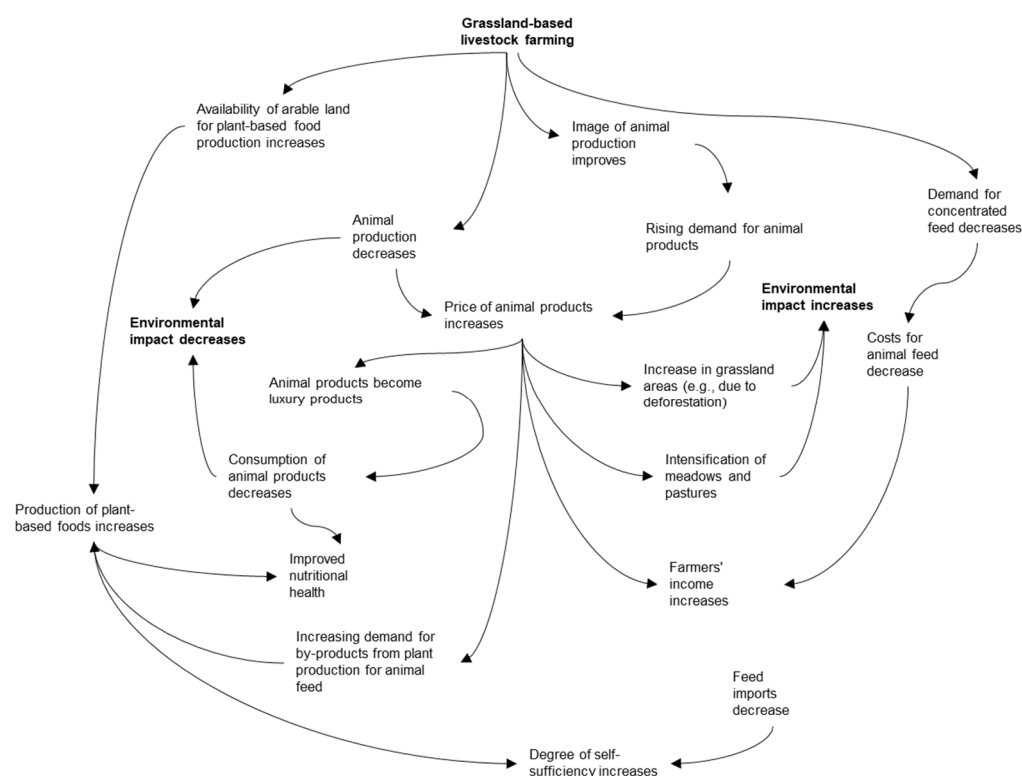


Figure 3. The possible impact of grassland-based agriculture based on the reviewed studies.

4. Discussion

The scenarios discussed illustrate how grassland-based livestock farming could serve as a viable alternative for more sustainable agriculture in the future. In all the studies reviewed, grassland-based livestock production is framed as part of a feed-no-food restriction. Alongside roughage-based ruminant farming, animal feed is restricted to waste and by-products from plant production, while existing arable land is primarily devoted to cultivating food for human consumption.

This approach has several direct effects: the availability of feed and the number of farm animals decline, while the land designated for human food production increases. Con-

sequently, the production of plant-based foods and the overall degree of self-sufficiency rise. Additionally, the reduction in livestock numbers helps mitigate negative environmental impacts.

The results are basically comparable to findings from global feed-no-food scenarios [9,22–24]. Various global studies have shown that the feed-no-food scenarios perform better from an ecological point of view, both compared to the current situation and compared to scenarios which would focus on intensification of livestock production [9,23–25]. Even though no comparison with an intensification strategy was carried out for Switzerland, significant ecological improvements were shown compared to the current situation [15,16,20].

However, it is important to note that the feed-no-food strategy is strongly linked to the demand restraints: the positive environmental impacts in addition to the increase in self-sufficiency are primarily due to a reduction in livestock and the associated lower meat consumption, which in turn would require major changes in societal consumption patterns [16,24,26]. Garnett et al.'s [27] review of studies on different feed-no-food scenarios shows that the potential animal protein consumption under these scenarios is between 11 and 32 g per person per day. Current per capita animal protein consumption in Switzerland is about 50 g per day [28].

At the same time, the studies, both globally and for Switzerland, show that the changes of a feed-no-food scenario primarily lead to a reduction in the monogastric population and that the quantities of available beef and milk decrease significantly less. From a nutritional point of view, however, this contradicts the dietary recommendations of the EAT-Lancet Commission, which primarily recommend a strong reduction in beef [4,29].

While various studies address the question of how many livestock can be kept with existing grassland resources, some of the studies raise the issue of the extent to which the use of grasslands for animal feed makes sense. The studies by von Ow [14], Baur and Flückiger [20], and van Zanten et al. [9] argue that reducing meadow and pasture areas could also be beneficial for nature. Based on the comparison of different scenarios, Müller et al. [26] conclude that Switzerland's existing grassland areas serve as a valuable asset for grassland-based agriculture. However, the scenarios also indicate a need for significant changes in consumption patterns, particularly towards reducing the consumption of animal products. This shift presents an opportunity, as it aligns with the goal of promoting a healthier diet and creates potential synergies. However, the question arises as to how this transformation would succeed. Mack and Kohler [19] show that the existing policy instruments (GMF payments) are not sufficient to bring about major changes. Further measures would be necessary on both the production and consumption sides. Zimmermann et al. [15] conclude that such a far-reaching change in diet requires a corresponding willingness on the part of the population, businesses, and politics. It is important to stress that none of the assessed studies included a predictive forecast. Therefore, no statement can be made on how probable such futures are or how they could be achieved.

5. Conclusions

Our findings show that the future of livestock production, particularly in shifting toward grassland-based systems, is closely linked with environmental, social, and economic factors. These factors will shape livestock production, just as livestock choices will influence these domains. Policy interventions will be critical in establishing pathways that guide both production and consumption. The results highlight key trade-offs associated with livestock futures, including those between environmental impact and production levels, as well as those among different environmental metrics. Although grassland-based livestock systems offer multiple benefits, the higher greenhouse gas emissions associated with ruminants present a significant challenge. We therefore recommend a continued focus on addressing these trade-offs, engaging a broad spectrum of stakeholders to balance food system priorities effectively. The weighing up of different societal objectives will be needed to decide to what extent an orientation of grassland-based livestock production in

Switzerland is to be prioritized. Based on the identification of normative scenarios, further research is needed on how to guide developments towards the desired pathway, which will require harmonized policies and actions throughout the food system.

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