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Land Use, Livestock, Quantity Governance, and Economic Instruments—Sustainability Beyond Big Livestock Herds and Fossil Fuels

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Abstract: The production of animal food products is (besides fossil fuels) one of the most important noxae with regard to many of the environmental problems, such as climate change, biodiversity loss or globally disrupted nutrient cycles. This paper provides a qualitative governance analysis of which regulatory options there are to align livestock farming with the legally binding environmental objectives, in particular the Paris Agreement and the Convention on Biological Diversity. Two innovative governance approaches are developed and compared: a cap-and-trade scheme for animal products and a livestock-to-land ratio. Both instruments are measured against the above-mentioned environmental objectives, taking into account findings from behavioural sciences and typical governance problems. Both approaches are generally suitable as quantity governance in animal husbandry if they are properly designed. In the end, a combination of both approaches proved to be particularly effective ecologically. All of this simultaneously demonstrates, on the basis of a rarely considered but ecologically highly relevant sector, how a quantity governance approach that is based on an easily comprehensible governance unit can function across all sectors and regions.

Keywords: livestock governance; economic policy instruments; emissions trading; livestock-to-land ratio; animal husbandry; food policy; climate policy; climate change; biodiversity loss

1. Introduction: Research Issue

Meat, milk, and eggs are set items on the menu of Europeans. The special treat of the former Sunday roast has become the ordinary. However, that comes at a price. The production of animal food of the current quantities is responsible for numerous global, regional, and local environmental problems. These include disrupted nutrient cycles, water, soil and air pollution, loss of biodiversity and climate change. Agriculture and livestock farming not only act as "perpetrators", but also as "victims", because they are also affected by environmental changes and climate change [1,2] (pp. 216–217) [3]. For example, changes in climate can have a massive impact on yields, as in the case of the severe drought that European agriculture experienced first-hand in the summer of 2018. However, the loss of biodiversity—keywords being pesticides and insect mortality—can also have fatal consequences for agriculture and animal husbandry.

The environmental impact, and specifically climate relevance of animal food production varies widely according to species and breeds and how they are adapted to the regional living conditions as well as life span as well as conditions and modes of husbandry, including the origin of feedstuff (fertiliser use, pastural farming, import). Numerous life-cycle-assessment studies show that, on average, animal food requires more land and is more damaging to the climate than vegetable food [4–8] (see Section 3 for details). At the same time, the world's population is estimated to reach 9 to 10 billion people by 2050, according to the United Nations prediction [9]. The Food and Agriculture Organization of the United Nations expects an increase in demand for milk by 62% by 2050 compared with 2005/2007, and for meat by 77% [10] (pp. 74–80). With their strong economic growth, developing and emerging countries are following in the footsteps of unsustainable European and North American consumption patterns [9] (p. 14), [11] (p. 5), [12] (p. 23), [13].

Assuming, however, that zero emissions in a maximum of two decades are required to ensure compliance with the 1.5-degree limit of Art. 2 paragraph 1 of the Paris Climate Agreement [14,15] greenhouse gas (GHG) emissions from livestock farming require an absolute cap. This paper therefore focuses on the discussion of innovative governance options that are strictly oriented towards the binding environmental goals under international law which allow for a quantity control of emissions. At the same time, it is essential to keep in mind the preservation and restoration of biodiversity in order to avoid conflicting goals between climate and biodiversity protection. However, as biodiversity is more difficult to measure and operationalise than GHG emissions, the focus of this study is on two instruments that address the cap on GHG emissions from livestock farming: emissions trading for the GHG from livestock farming and a livestock-to-land ratio. This selection is based on the fact that elsewhere [15–18] it has been shown in detail that the previous European Union (EU) regulatory law and EU agricultural subsidies, but also cautious economisation approaches such as moderate meat taxes, are structurally not sufficient in any way to meet the requirements of Article 2 paragraph 1 PA (see below in more detail).

While emissions trading systems already exist in many countries and for various sectors, there is a lack of concrete models in the area of agriculture. In New Zealand, the inclusion of agriculture in emissions trading was planned, but implementation has not taken place [19]. The concept of a climate-linked livestock-to-land ratio follows the idea of linking the available agricultural land to the cap on GHG emissions—a procedure which is unprecedented. Problems of disrupted nutrient cycles in the form of nitrogen (N) and phosphorus (P) surpluses caused by concentrated livestock farming are thus addressed at the same time. In a comparison of both instruments based on typical control problems known from sustainability research, a detailed account is given of whether emissions trading or a climate-linked livestock-to-land ratio is better suited as the main instrument for the governance of animal food.

2. Methodology

With regard to the two governance instruments, a qualitative governance analysis is done (complemented by a short literature review of the ecological effects of livestock farming). This analysis determines the effectiveness of potential or real governance instruments on the basis of a given objective by taking findings of research on human behaviour and typical governance problems into account. In this paper, the above-mentioned Article 2 paragraph 1 of the Paris Agreement serves as the objective. This norm obliges all states worldwide to limit global warming to 1.5 °C compared to pre-industrial levels, which implies global zero emissions from fossil fuels in all sectors and drastically reduced emissions in other sectors such as animal husbandry—as well as a compensation of the remaining emissions—in a maximum of two decades (described in detail, also with regard to the ratio of Articles 2 and 4 Paris Agreement [14,15]). However, the comparison of emissions trading and livestock-to-land ratio as governance instruments cannot be based on a direct empirical experience, since instruments for zero emissions in two decades have so far not been observable, but are only theoretically constructed. A qualitative governance analysis is particularly suitable for the assessment of new instruments that cannot yet be observed in reality. It is based on findings of behavioural science from various disciplines (such as sociology, economics, socio-biology, psychology, cultural studies, ethnology, etc.), which make it possible to anticipate how people will react to known governance incentives. Motivational factors that influence human action—as can be determined from experiments, participant observation, surveys, socio-biological analyses and other methods—are self-interest, values, emotions, conceptions of normality, path dependencies, and problems of collective goods (on the statements of this entire paragraph see also [15,17,18,20,21].

Factors of behavioural motivation (among consumers, farmers, entrepreneurs, politicians, etc.) are also the basis for identifying certain governance or control problems which can be expected as shown by the aforementioned sustainability research. These problems impair the effectiveness of existing sustainability governance instruments: lack of rigour in contrast to the objective, shifting effects, rebound effects, enforcement deficits and problems of depicting. The lack of rigour describes how adequate an instrument is in relation to the pursued objective. Since two instruments that have not yet been implemented in reality are compared, this aspect is concerned with how structurally suitable the instrument is to stay within an overall goal such as the global 1.5 °C limit and thus to achieve zero emissions globally within two decades. Shifting effects refer to emissions or resource consumption which are produced in other sectors, to other locations or to stop the harmful effect on one environmental problem while increasing pressure on another as a result of a sustainability policy measure. Rebound effects describe the phenomenon that the improvement of the resource efficiency of products through their increased use compensates for the ecological benefit or at least compromises it. Deficits in enforcement exist when political measures or laws are not effectively implemented in practice. The effective enforcement of the reduced production of animal foodstuffs can, for example, be facilitated if the number of norm addressees is kept as low as possible, because a large number of those affected make enforcement more difficult. A similar assumption can be made for the complexity of a norm: The more complex the object of regulation, the more difficult it becomes to monitor and sanction infringements effectively. The term "problems of depicting" refers to the difficulties frequently encountered in sustainability research in accurately measuring, calculating and identifying sustainability problems, which also make it more difficult to address these problems accurately. For reducing the production of animal food, an easily comprehensible governance unit or control parameter is advantageous, as it facilitates the implementation.

Given that sustainability challenges such as climate change are difficult to solve because of the behavioural dispositions mentioned above and the governance problems resulting from these dispositions, this article will assess in Section 4 which policy instruments can respond adequately to these problems—under the auspices of the above-mentioned normative targets. Behavioural dispositions are one reason certain governance problems, such as rebound effects, etc., are to be expected. On the other hand, it is not possible to simply observe the configuration of governance instruments in reality that have not yet existed in this form (such as complete decarbonisation within a few years). Nevertheless, further empirical insights on already existing instruments will underline the findings on instruments that can be drawn from behavioural research in this contribution, e.g., the fact that GHG emissions are macroeconomically shifted can be measured to some extent (albeit with severe difficulties) by determining the GHG intensity of products on the basis of technical data and combining them with statistical import and export data.

Another important remark: The appropriate level of emissions in the livestock sector to implement the zero-emission target of the Paris Agreement depends on complex factual questions and on questions of political and legal consideration of various objectives. Reducing the absolute number of livestock is with high certainty inevitable to meet sustainability targets, as is elaborated below. However, for reasons of world nutrition and because of the beneficial (and in other places at least not harmful; see Section 3) effect of extensive grazing livestock farming on biodiversity, this does not imply that the number of animals kept has to be zero or even extremely low. In addition to Article 2 paragraph 1 Paris Agreement, another objective is included in the consideration of this paper: The Convention on Biological Diversity (CBD) in conjunction with the Aichi Targets contain the binding obligation of states to stop and reverse the loss of biodiversity and ecosystems in a timely manner [15,17,18,22]. After all, the number of animals will tentatively have to be chosen in a way that (1) together with other residual emissions, their compensation in the form of sinks is possible, (2) nutrient cycles can still be closed and (3) the biodiversity-promoting forms of livestock production remain possible. Having said this, it is not possible to present an exact figure here, since these demands take us to highly complex empirical questions (also regarding the nature of compensations and ongoing improvements of productivity in agriculture) that probably nobody can answer exactly at the time being.

Given the need for compensation (and given the risks and uncertainties of geoengineering), the land use and forestry sector will have to become net sinks for GHG in the future in order to compensate for some residual emissions that will remain even if a cap zero for fossil fuels is established (due to agriculture and process emissions from industry). For instance, Willett et al. [23] postulate that a sink capacity of −10 $GtCO_2eq$ has to be reached by the land use sector latest in 2100 to stay within the planetary boundaries and the Paris temperature limit. Thus, according to Willet et al. [23], changing to a predominantly vegetarian or vegan diet provides around 80% of the required emission reduction potential. Within Europe and Central Asia, the reduction potential of red meat consumption is suggested to be even higher and amounts to over 70% [23] (p. 26), [24]. Regarding Europe, Westhoek et al. [25] calculated that halving the consumption of meat, dairy products and eggs would reduce net GHG emissions from the agricultural sector by 25–40%. However, in light of the ambitious target of the PA and the need to offset all remaining GHG emissions by sinks in the future, these modelling results also indicate that halving the production of animal derived foods within high income countries will probably not be sufficient. This remains true regardless of possible mitigation options in agriculture and productivity improvements in the livestock sector (e.g., feeding strategies that reduce CH_4 emissions) or relatively low-emission modes of livestock farming because the achievable emission reductions by those strategies remain rather small and cannot substitute for a significant reduction in livestock production, as we will see below [26–33].

Regardless of these uncertainties, an overall design for quantity governance instruments on livestock can be developed in the present paper. In the following analysis, we will primarily focus on possibilities of restricting livestock farming in order to meet the requirements of the Paris Agreement and not on the CBD, also because biodiversity describes a spectrum which is much more vague and complex than is the case with GHG emissions and temperature limits, which are variables relatively easy to grasp.

3. Natural Scientific Background: Environmental Problems of the Production of Animal Foodstuff

Keeping in mind the complexity of environmental problems is the basis for the debate on ap-propriate environmental policy measures to reduce environmental problems in relation to the above-mentioned objectives. Through intensification and irrigation, agriculture has produced enormous increases in yields and thus contributed significantly to food security. At the same time, intensification and specialisation have had a negative impact on ecosystems [2] (p. 196), [34] (p. 41), [35,36], [37] (p. 40, 135). Also, due to fodder and pasture farming, livestock farming accounts for 70% of the EU's agricultural land, which increases the environmental impact of agriculture and—in turn—undermines food security [38] (p. 21), [12] (p. 31), [39,40]. However, quantifications of the overall impact of livestock farming is highly complex and will always be controversial when generalised. Results vary according to i.e., species and breeds, animal density, feed production and acquisition, lifespan, region and their respective natural characteristics, animal treatment, manure management. Additionally, the impact varies according to the environmental asset looked at, i.e., soil, water, nutrient cycles, and resource input, GHG emissions and the protection of biodiversity as such. This section will provide a broad overview of the main environmental issues occurring in the context of livestock farming in general by their origins. It will show that the current level of livestock farming as a whole cannot be environmentally maintained. Section 4 will offer a practical solution for a governance structure to inhibit negative impacts specifically on the climate and also on other environmental issues as described below.

In particular intensive animal husbandry—and the associated feed production as well as the accumulation of manure—is one of the large emitters of GHG and thus contributes extraordinarily to global climate change and the global loss of biodiversity. At the same time, they represent the greatest human influence (not on the environment in general, but) on the global N and P cycles. N and P are essential nutrient elements for plant growth. With the "Green Revolution" in the 1960s, the use of synthetic N fertilisers increased nine times worldwide and that of P tripled—with the result that natural nutrient cycles are disrupted [41] (p. 19), [42,43] (p. 67). However, the decoupling of land and livestock also plays an essential role in this context. Feed is often produced in monocultures or close crop rotations far away from animal husbandry, which requires the intensive use of agrochemicals such as pesticides and mineral fertilisers [44], [17] (p. 47, 102). Mineral N fertilisers are synthesised from atmospheric N using the highly energy-intensive Haber-Bosch process [41] (p. 8,16). P on the other hand, has to be mined unless fertilisation is done organically or with recycled materials in the future. Mineral phosphate reserves are limited, unevenly distributed worldwide and increasingly contaminated with the heavy metals uranium (U) and cadmium (Cd) [17] (pp. 49–57), [45] (p. 40).Thus, the intensive feed production shows already negative environmental impacts on soil and water quality and not least on the protection of climate and biodiversity. Furthermore, importing animal feed leads to a nutrient surplus in areas with intensive animal husbandry because in those areas more nutrients are applied through the liquid manure than plants can absorb [46] (p. 135), [47] (p. 188). Surpluses are released into the air as nitrous oxide (N_2O), ammonia (NH_3), nitrate (NO_3^-) and other N compounds as well as P compounds in ground- and surface waters. This enhances or causes the eutrophication of water bodies; algal blooms and oxygen deficiency lead to marine or aquatic biodiversity loss because other aquatic plants and animals are displaced or suffocated [40] (p. 34), [47] (p. 180). Likewise, land areas with high animal density tend to show nutrient surpluses [25] (p. 200), [47] (p. 186), [48].

This connection is further substantiated by Leip et al. [49] who compare the N intensity of various European foods. Here, dairy is considered along with meat, therefore, there is no differentiation in terms of N efficiency. The study is based on a cradle-to-gate analysis, so only the total of emissions from livestock lifespans is taken into account. Other studies support this approach in showing that the difference between the two is rather small on average [35] (p. 30). Since, for the governance approach proposed, lifespan and number of animals are relevant, this seems to be appropriate in this paper. Accordingly, animal products (led by beef) have considerably higher values than vegetable foods. Metson et al. [50] show a consistent finding for the P intensity of animal foods. The application and storage of N fertilisers lead to NH_3 and NO_x emissions in addition to the climate-relevant N_2O emissions still to be considered, which among other things lead to the formation of tropospheric ozone and particulate matter and thus impair vegetation and the human respiratory tract [49], [51] (p. 1315), [52] (p. 14). In Europe, three quarters of NH_3 emissions are attributed to livestock farming, which accounts for the entire management of manure (livestock buildings, storage sites and use of organic fertilisers, urinating grazing animals [53], [54] (p. 10)). Nitrate pollution in waterbodies, especially in groundwater, and air pollution are examples of unsustainable situations with an economically negative impact, as well, either in water purification or in the sanitation system [52] (p. 15), [55].

In addition to the air and water pollution described above, agricultural N—that is massively generated, especially with high livestock densities—also has an impact on the climate, namely when it occurs in the form of N_2O, a GHG that is approximately 300 times more harmful than carbon dioxide (CO_2) over 100 years [56] (p. 714). It is produced during the storage and processing of N fertilisers and during the spreading of (organic or synthetic) N fertilisers on pasture and arable land [35] (p. 20). Other GHG from livestock farming are CH_4 and CO_2. To compare climate impact, GHG are often converted into CO_2 equivalents (CO_2eq). CH_4 corresponds to 34 CO_2eq [56] (p. 714). CO_2 emissions result from land use changes when fodder crops or pastures expand and the carbon (C) stored in the soil and vegetation is released. Moreover, fossil-fuel use for the production of energy-intensive N fertilisers, stables and machinery, tillage, harvesting, the processing and transporting of animal feed as well as for the processing, packaging, transport, and storage of the final animal products is also one of the GHG sources of livestock farming [35] (p. 20). In short, of GHG emission along the production chain of animal food include the emission of CO_2, N compounds and CH_4 caused by (1) feedstuff production (especially land use changes and fertiliser use in the context of the production of protein feed), (2) enteric fermentation of ruminants and manure application, (3) fossil fuel-based processes (see also Figure 1). In total, about 12–17% of GHG in Europe originate from animal husbandry and a quarter of emissions worldwide stem from agriculture and forestry [4] (p. 9), [39] (p. 39), [57] (p. 7).

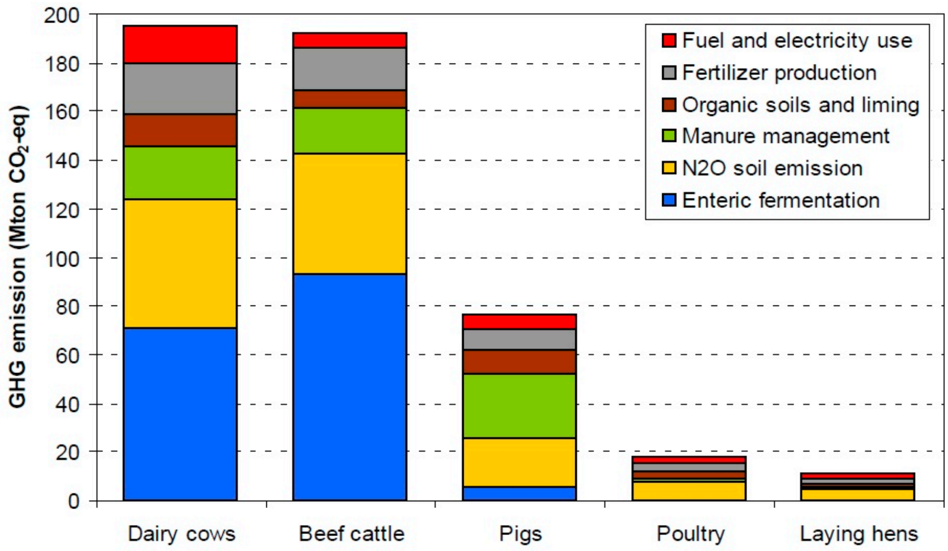

Figure 1. Total of GHG emissions from livestock farming in the EU27 by source of emissions [38] (p. 25). Not included are emissions from direct or indirect land use change. Data is based on EUROSTAT under Intergovernmental Panel on Climate Change (IPCC) standards. Manure management considered animal type, average annual temperature and manure system. Different types of livestock farming were accounted for, e.g., by regarding the different feed and forage types per sector and then producing the average for each sector.

Furthermore, animal husbandry, as the most important element of agriculture [4–8,39], can have strong direct and indirect impacts on biodiversity. The problems caused by N and P eutrophication have already been mentioned. According to the European Commission, 26% of European species are endangered by pollution from agricultural fertilisers and [58] (p. 11)—which is hardly surprising given the lack of implementation of the Directive on the Sustainable Use of Pesticides [59], the Nitrates Directive [60] and the Water Framework Directive [61] in most Member States [48,62,63]. Land use changes, such as the conversion of grassland or forest areas to arable or pasture land, are also a direct threat to biodiversity. European animal husbandry is also responsible for enormous land consumption and land use changes outside Europe via the already mentioned feed imports. In South America, for example, the rapidly increasing demand for soya has led to an expansion of agricultural land—combined with a strong repression of natural ecosystems such as rainforests and savannah, with serious consequences for biodiversity and GHG emissions [47] (p. 181), [64] (pp. 4–22) [65]. Furthermore, soil plays an important role in the global carbon cycle. It contains more carbon than the atmosphere and vegetation together and is therefore a significant carbon sink. Already slight losses of organic matter in the soil cause the release of previously bound C which can have a major impact on the atmosphere [46] (p. 55). Arable land usually contains less organic matter and thus less bound carbon than forest soils or grassland. Converting forests and grassland into arable land thus decisively contributes to climate change [66] (pp. 35–39).

For all the aforementioned reasons, the overall climate impact of livestock farming remains high, even when taking into account animal husbandry on land which is not suitable for any other agricultural use and extensive pasture farming. In those cases, the animals might even positively affect biodiversity and soil quality and reduce the negative GHG balance [67,68]. Exclusively extensive and side-adapted pasture farming will however only provide for much smaller amounts of animal products and thus require also changes in consumption patterns [23,24]. In any case, such empirical insights are important for the design of governance instruments in the following sections.

Looking at the bigger picture of this literature review of the ecological effects of livestock farming, it becomes clear that the current production of animal food e.g., in the EU is far from "sustainable" and is responsible for a large part of the environmental impacts usually subsumed under environmental problems of agriculture. In the agricultural policy discussion, animal husbandry has not yet played a significant role despite the many and sometimes severe problems briefly described here [12] (p. 78)—which as mentioned in the introduction (in detail [21])—leads to inadequate legislation. In summary, the key challenges for the sustainability governance of animal foodstuffs are, on the one hand, the creation of a system of animal husbandry that is in line with the climate protection requirements of Article 2 paragraph 1 PA and, on the other hand, closing disrupted nutrient cycles, which in addition to the use of agrochemicals, are at the origin of numerous subsequent problems for biodiversity, human health as well as soil and air quality.

4. Results: Approaches of a Sustainability Governance for Animal Products

4.1. Purely Technical Strategies Versus Frugality by Means of Quantity Reduction

To solve the problems described above and to achieve the objective set by Article 2 paragraph 1 PA, two sustainability strategies are usually considered in order to reduce the environmental impact of the production of animal foodstuff: technical measures to reduce the ecological consequences (e.g., emission intensity, land consumption) or measures to reduce the number of animals [39]. In the literature, several technical reduction measures are primarily discussed that are intended to reduce the intensity of pollution caused by animal food production. These include changes in agricultural practices and increases in the efficiency of animals or their feed, which will reduce GHG [2,27], [35] (p. 394), [69,70]. For example, CH_4 emissions may be reduced through the composition of feed or feed additives, [27] (p. 454), [71,72]. Regarding the management of farm manure, air- and seep-proof storage as well as anaerobic digestion in biogas plants for slurry are available measures for reducing emissions. In addition, optimal fertiliser application (timing, technology, fertiliser requirement of the plants) reduces emissions; nitrification inhibitors can also be used to reduce N_2O formation [27]. Increases in productivity of feed cultivation and of the animals themselves (through breeding, better health, and fertility) also reduce the emission intensity [27]. Multi-unit crop rotations, which include legumes as intermediate or main crops, reduce the need for fertilisers, improve soil properties and can also reduce the emission of N_2O and CO_2 during the production and application of fertilisers [73].

However, some of these techniques for GHG reduction are also quite questionable: an intensification of agriculture can lead to other environmental problems, such as disrupted nutrient cycles, loss of biodiversity, air, water, and soil pollution [2] (p. 196), [26–33], [74] (p. 3). Interventions in the digestive metabolism of animals, for example through feed additives, can impair animal sanitation and often only lead to short-term CH_4 reductions because CH_4-forming microbes adapt quickly to the treatment [27] (p. 454), [75] (p. 44). When assessing CH_4-reducing feeding habits, the GHG emissions of feed production must also be taken into account. A study by Vellinga and Hoving [76] has shown that if, in order to reduce CH_4 emissions from the digestion of dairy cows, grassland and pastureland is converted into maize field for animal feed cultivation, the resulting carbon loss in the soil far exceeds the CH_4 savings. To evaluate the savings potential of CH_4-reducing feeding, feed production must therefore be included in the analysis. Wirsenius and Hedenus [77] (p. 244) estimate the technical mitigation potential of EU agriculture at 15% by 2020, taking into account improvements in feed composition for CH_4 reduction, manure management, fertiliser application, use of nitrification inhibitors and pH reductions in manure, and use of 10% renewable fuels in transport when 25–50% of farms apply these techniques (for reduction potential in agriculture see also [78]). This limited potential makes clear that technical improvements alone will not be sufficient to significantly limit GHG emissions from animal husbandry, as emissions are found to be fundamentally linked to the biophysical processes in agriculture [26–33,79]. The digestive system of ruminants inevitably produces CH_4 and the production of N_2O in connection with fertilisation is part of the N cycle [77] (p. 244), [80] (p. 163). Without a reduction in animal food, solely through productivity increases, technical measures and switching to agricultural practices such as organic farming, limiting global warming to 1.5 °C probably cannot be achieved [21] (p. 320), [29] (p. 89), [75] (p. 76), [81] (p. 174), [82].

Nevertheless, neither the EU's current climate policies nor its Common Agricultural Policy regulations aim to achieve a reduction in livestock numbers. This takes us to the question of the most effective policy instruments for quantity governance in terms of animal husbandry. As shown elsewhere, it would also be difficult to achieve ambitious quantity reductions by using basically subsidy law or individual improvements in regulatory law of agriculture. This is due to the fact that instruments focusing on individual actions or products hardly have the potential to address absolute quantity reductions and face the above-mentioned typical governance problems such as lack of rigour, rebound effects, shifting effects, etc. (in more detail [21]). The debate on EU's Common Agricultural Policy and its limited relevance in comparison to instruments for zero fossil fuels and drastically reduced animal husbandry were discussed in more detail elsewhere [18,20,21,83,84]. Achieving reductions in quantities is even less likely if using purely voluntary or informal measures to stimulate frugality in consumption or production [15], [74] (p. 77), [85] (p. 498), [86,87].

Following the debate in governance theory (see e.g., [15]), quantity limitations directly address the quantity, which will then indirectly affect consumers as a price increase, or address the price itself e.g., by means of taxes (which will indirectly address quantities). According to Article 113, 192 Treaty on the Functioning of the European Union (TFEU), however, EU-wide harmonisation of taxes requires unanimity of the Member States. In addition, a purely nationally drastic pricing of animal food will have little effect because in the open EU market the products could simply be imported. Therefore, taxes and options on national level are not pursued further here. This is also due to the fact that e.g., meat taxes, feed taxes or N levies only address individual aspects of livestock products (more detailed on this [18] (pp. 341–351), [80,81,88,89]). Instead, as announced, a cap-and-trade approach and a livestock-to-land ratio will be discussed in the following, as well as a possible combination of both policy approaches. A cap-and-trade system has the characteristic of setting an absolute upper limit on noxae. However, a reduction and capping of the number of animals could also be conceivable by means of binding livestock numbers to available land area.

4.2. Emissions Trading with Greenhouse Gas Emissions from Animal Husbandry

One option for regulating emissions from livestock farming is to establish a cap-and-trade scheme with regard to its GHG [15,18,21]. A legal basis in EU law for establishing a system of quantity control is provided in Article 192 TFEU, according to which corresponding laws can be passed by the ordinary legislative procedure which requires the qualified majority in the Council of Ministers (and a majority in the European Parliament). As stated elsewhere, a cap-and-trade approach is particularly compatible with the basic principles of liberal democratic constitutions, flexible, cost-efficient—and, above all, ecologically effective [11] (p. 6), [15,18,90], [91] (p. 8). This is because spatial and sectoral shifting effects as well as rebound effects can be avoided, if cap-and-trade is broadly-based in terms of the regions and the sectors included. If it is furthermore linked to an easily comprehensible governance unit or control variable—such as fossil fuels—enforcement is also easily feasible (more detailed on this [15,18]).

While there are already 25 cap-and-trade schemes (addressing emissions, even though a clear cap is not always provided) worldwide for emissions from one or more of the sectors energy, industry, fossil fuels, waste and transport, advances into agriculture or forestry are an extremely rare exception [91] (p. 40). New Zealand's emissions trading system was originally conceived as the first trade covering "all sectors, all gases". However, successful lobbying by the agricultural sector led to postponing the inclusion of agriculture in emissions trading indefinitely in 2012; forestry, however, is already covered [91] (p. 40), [92], [93] (p. 3). Kazakhstan currently considers implementation of a comprehensive trading scheme [94] (p. 124), [95] (p. 8). The planned introduction in New Zealand, together with some publications on emissions trading in agriculture, provides some ideas for the analysis below [15,18,19,21,88,89,96]. In any case, several detailed questions must be answered in any cap-and-trade system (auctioning or free issuance of allowances; flexibility of allowances; exact trading periods; trading platforms; market intervention mechanisms for possible market stabilisation). Since these details do not play the main role for the ecological effectiveness of a system, they are not deepened here for space reasons.

However, there are some design issues which are of crucial importance in terms of the ecological effectiveness of cap-and-trade. Those questions are analysed in the following, based on the objective in Article 2 paragraph 1 PA and the above-mentioned findings on governance problems (and behavioural motivation). These questions concern norm addressees, selected governance units or control parameters and along with it the emissions recorded, whether a system is binding, a cap in accordance with the objective pursued as well as effective controls and sanctions [15,89,90]. Since Article 2 paragraph 1 PA implies zero emissions in two decades, the emissions cap would have to be chosen in a way that the remaining emissions can be offset through the management of land, forests and in particular wetlands, as has already become clear [97] (pp. 872–881). Furthermore, contrary to a published opinion [20,96,98] the objective is not to regulate animal husbandry and fossil fuels in one joint emissions trading scheme. Despite the possible cost-efficiency of such broad approaches [99] (p. 4), [100] (p. 20), [101] (p. 10), the fact that GHG emissions from fossil fuels need to reach zero eventually, while those from animal husbandry—given the above-mentioned discussion on biodiversity and nutrient cycles—cannot be entirely eliminated [21] contradicts a uniform approach from the outset.

The key challenge is to choose the addressees and the control variable for the respective cap-and-trade system. This will be analysed in the following (in more detail see [22]). In view of the difficult motivational situation mentioned in Section 1 with regard to sustainability and in view of potential (among other governance problems) shifting effects, enforcement deficits and problems of depicting, it is essential that the control variable and the norm addressees can be easily and fully captured at low cost [15,18], [19] (p. 20). With regard to emissions trading systems for the regulation of fossil fuels, it is called downstream approach if GHG are regulated at the point where they enter the atmosphere (such as in the EU Emissions Trading Scheme; EU ETS). On the other hand, if a system starts regulating further up the production chain where the fuels are produced or imported, this is called an upstream approach [15,101], [90] (p. 10).

If we were to follow the EU Emissions Trading Scheme's (EU ETS) logic of regulating GHG at their source [101], all livestock farms would need to be regulated. There are about 6.2 million livestock farms in the EU [102]. By comparison, the current EU ETS regulates around 11,000 installations [103]. Even if smaller companies (by whatever standard) from emissions trading were to be exempt, there would still be a large number of units to be regulated. In addition, the definition of a minimum size of farms poses further problems as this would create incentives to circumvent emissions trading by dividing livestock farms into smaller plants. Also, a complex fight about the minimum size for regulation might likely lead to a political dead lock [89], [104] (p. 208). Furthermore, such a partial regulation could also be regarded as suffering from a lack of rigour with regard to the Paris climate target.

When constructing the inclusion of agriculture into their emissions trading system, the New Zealand government considered the milk and meat processing industry as well as fertiliser producers as regulatory points due to the large number of small enterprises [19]. This would massively reduce the number of parties to the emissions trading. There are slightly more than 13,000 slaughterhouses, 5350 dairies and about 1400 producers of fertilisers and N compounds in the EU [102].

For both regulatory options—livestock farms or processing and supply companies—the questions arise which emissions are being monitored and how they can be monitored at the location of the addressees to form a basis for the allocation of certificates. Figure 1 on GHG emission profiles of the European livestock sectors of the EU27 gives an impression of the magnitude of the different emission sources [38]. Emissions due to land use changes were not taken into account in the study. They vary greatly from region to region and the methods used to calculate them are still controversial [35] (p. 41), [105,106]. The sources and sectors involved in land use changes also make it difficult to allocate their emissions. The graph shows that, when distinguishing by animal category, cow's milk and beef production are by far the largest emitters, accounting for more than 70% of total GHG emissions from livestock farming in the EU27. If sorting by emission sources, CH_4 from enteric fermentation leads the list with 36%, followed by N_2O emissions from soils with 28% and N_2O and CH_4 emissions from manure management with 13% [38].

Aspects of the current EU climate policy (for an overview see [21]) will now serve as a starting point for considerations as to which emissions could sensibly be regulated by a cap-and-trade system for the GHG of animal food production. Table 1 separates the emission sources into emissions from the use of fossil fuels and emissions that are not caused the use of fossil fuels. Some of these emissions are already covered by the EU ETS. These include CO_2 emissions from fossil energy consumption in the production of mineral fertilisers and in feed processing, as well as CO_2 emissions from fossil energy consumption in livestock facilities and the construction of buildings and equipment. Also, they include CO_2 emissions from fossil energy consumption during the processing, packaging, and cooling of animal products. To reduce these fossil fuel-based emissions, a drastic reform of the EU ETS is needed, based on an integration of all fossil fuels into the system (today only electricity and some industrial sectors are included whereas heating or traffic emissions are still left aside). At the same time, a much more ambitious cap oriented to a step-by-step reduction of fossil CO_2 emissions to zero emissions within one or two decades is needed in order to achieve the climate target of 1.5 °C set out in Article 2 paragraph 1 PA (on this type of approach see for more detail [15,18,90,101].

For a cap-and-trade system covering GHG of animal husbandry, we still need to discuss the emission sources marked in light green in Table 1, which from 2021 will fall partly under the Effort Sharing Regulation and partly under the LULUCF Regulation (LULUCF = Land use, land use change and forestry, for more details on this see [21]). The methods to quantify CO_2 emissions from land use are the most controversial so far [20], [35] (p. 41). They are not suited for a regulation under a cap-and-trade system, as that requires the highest possible level of precision in accounting for the quantity emission. That is because the certificates are assigned a market value, and imprecision risks creating loopholes in the trading system [15,20], [21] (p. 326), [90] (p. 28). However, land use changes could indirectly be addressed by economic instruments by making animal products scarcer and thus more expensive because at the same time the demand for land use changes decreases [15,20]. In addition, one could also price land use or part of it in the form of animal feed as such (see briefly at the end of the text).

Then, the question arises as to how the emissions from animal husbandry and agriculture (CH_4 from enteric fermentation, N_2O and CH_4 from manure storage and processing, N_2O from the application of N fertilisers, excretions from grazing animals and crop residues on the fields), which are so far not covered by emissions trading, could be covered by emissions trading. In the following, two options for the choice of the governance unit are analysed: a recording of GHG emissions at farm level—and the use of a general emission value per animal or per kilogram of product. An emission calculation at farm level seems obvious because emissions—as with the existing EU ETS [101]—would be recorded where they occur. Their determination at farm level could, for example, include information on mineral fertiliser and feed purchases, feed cultivation areas, feeding, soil cultivation methods, manure management and livestock numbers [89] (p. 17), [96] (p. 665). The advantage of this option is that climate-friendly practices would be directly encouraged as particularly climate-friendly farmers would be rewarded. The recording at farm level would lead to animal husbandry enterprises taking reduction measures that are the easiest and most cost-effective to implement for their individual circumstances. Individual reduction measures include the reduction of CH_4 from digestion, for example through the use of feed additives or a change in feed composition, but also to the reduction of the number of animals if other reduction measures no longer provide cost benefits [27] (p. 454), [30] (p. 11).

Table 1. GHG emissions from the production of animal products (following [35] (p. 7)), differentiated by the respective EU climate policy regulation from 2021 and by fossil and non-fossil emission sources.

Activity	Gas	Source	EU Climate Policy Regulation from 2021
Enteric fermentation	CH_4	Digestion of ruminants	Effort Sharing Regulation [1]
Farm manure	CH_4	Emissions from storing and processing farm manure	Effort Sharing Regulation [1]
	N_2O	Direct and indirect N_2O emissions from storing and processing farm manure	
Feed stuff	N_2O	Direct and indirect N_2O emissions from:Direct and indirect N_2O emissions from: • Application of farm manure • Application of synthetic fertilisers • Excretions of grazing animals • Crop residues on the field	Effort Sharing Regulation [1]
		Emissions from land use change	LULUCF Regulation [1]
	CO_2	Emissions from land use change	
		Changes in the carbon stock of the soil caused by land use	
		Fossil energy use for growing and transporting feed stuff	Effort Sharing Regulation [2]
		Production of mineral fertilisers	EU Emissions Trading Scheme 3
		Fossil energy use for operating machinery for processing feed stuff	
Plants	CO_2	Fossil energy use for lighting, cooling, heating, ventilation, appliances	EU Emissions Trading Scheme 3
		Fossil energy use for the construction of buildings and equipment	
Processing and marketing of animal products	CO_2	Fossil energy use for processing, packaging, cooling	EU Emissions Trading Scheme 3
		Transport of animals and animal products	Effort Sharing Regulation [1]

Note: [1] Emissions covered by the Effort Sharing Regulation [106] and the LULUCF Regulation [107], [2] Fossil fuel emissions covered by the Effort Sharing Regulation, [3] Fossil fuel emissions covered by the EU Emissions Trading Scheme.

The disadvantage of this initially promising approach, however, is the immense effort involved in recording and monitoring the multitude of agricultural practices relevant to GHG (differing emission intensities according to species and form of livestock farming) [21], [88] (p. 396), [100] (p. 20). Even now, environmental standards in agriculture are often not complied with, and detailed inspections have limits—which is another reason regulatory law in the agricultural sector has often not been very successful, yet [17,21]. In other words, such an elaborate approach leads to high transaction costs for norm addressees and authorities [57] (p. 223), [80] (p. 162), [88,89,96]. This, in turn, renders enforcement deficits highly probable, as they are known from regulatory law, particularly in view of the motivational situation in the sustainability sector described above. In general, the monitoring, reporting and verification (MRV) of agricultural emissions is much more complex than that of the combustion of fossil fuels [20], [89] (p. 9) which leads to major problems for small emitters in particular [108] (p. 80).

Therefore, the use of approximate values for determining emissions which are based, for example, on the Intergovernmental Panel on Climate Change (IPCC) guidelines for national GHG inventories could be a real opportunity as a base for MRV in agriculture [96] (p. 665), [89] (p. 17), [109]. Most of the data required for this is already collected for existing agricultural regulations and applications for subsidies under the EU Common Agricultural Policy [89] (p. 11), [96] (p. 665). To provide farmers with appropriate software for GHG modelling at farm level, there is further need for development [89] (p. 11), [100] (p. 24). The New Zealand Overseer Programme, which was also considered to be a monitoring tool in New Zealand emissions trading, could possibly serve as a model [19] (p. 16).

One way of reducing transaction costs is to use general or output-based emission values per animal or per kilogram of product [88] (p. 398) similar examples with meat taxes [80], [81] (p. 157). That way, the control variable for a cap-and-trade system would be much more tangible, since it would be easier to measure objectively the number of animals or the quantity of animal products than emissions from a farm keeping animals that can be determined on the basis of numerous characteristic values [80,110]. Since the emission intensity of livestock farming varies among others from region to region [38] (p. 24), the emission values could be based on regional or national average values instead of EU-wide values, which are determined using standardised methods such as the IPCC guidelines. If necessary, these generalised emission values can be further differentiated by distinguishing between different production methods, e.g., manure management or grazing or pure stable farming [88]. The more accurate the generalised emission values are in relation to the actual emissions, the fairer the system will be because the emission certificates to be made available are more closely oriented to the actual emissions. However, here too, it remains a trade-off between the accuracy of emission calculation (and control) on the one hand and transaction costs and the associated enforcement deficits on the other [89] (p. 17).

The general emission value can be related to various output measurands: to the animals themselves (heads), to the number of animals per year or to kilograms of an animal product. This decision has an impact on the incentives given to livestock farmers and on the choice of where to regulate. The most tangible, as objectively easy to grasp, is the individual animal. Depending on the animal type and the mode of husbandry, an average value could be calculated for the GHG caused by an animal over its lifetime (excluding emissions from transport and fossil energy consumption and LULUCF emissions). The emission certificate would then have to be shown once at the end of the animal's life. Possible regulatory points for such an approach would be the livestock farmers or the slaughterhouses. The high number of norm addressees speaks against the first option. If, on the other hand, the certificates are due in the slaughterhouses, there is at least a little risk of illegal slaughter in order to avoid cap-and-trade. Irrespective of the choice of the regulatory point, a generalised emission value per animal encourages the highest possible animal yield (meat, milk, or eggs), because the higher the yield of an animal, the lower the certificate costs. Therefore, looking at animal welfare, this approach would be less advantageous. The situation is very similar with fixed emission values per number of animals per year. Animal owners would be considered to be the only point of regulation here, because only they would have this information at their disposal. In that case, certificates must not be presented once per animal, but annually for the number of animals. However, a determination of output-based emission values per kilogram of animal product would prevent the above-mentioned pressure to increase performance because with that option the weight of the animal product would be the basic factor for the certificate estimation, not the performance of the individual animal. This version would probably also be more accurate, as the milk yield of a cow, for example, would be better represented than with an average value per dairy cow.

The governance unit (or control parameter) should therefore be the animal product as such, modifiable in general through factors such as grazing. Both livestock farmers and processing industry can then be considered to be norm addressees. The dairies could provide certificates for milk and the slaughterhouses those for meat. Certifying emissions of eggs could be regulated at the level of the producer (in the case of direct marketing) or at the level of the first buyer. In the case of animals supplying meat, the slaughter weight should be used for measurement because if only the consumption weight were the basis for measurement, there would be an incentive to declare parts as waste. In the case of dairy cows and laying hens whose meat can also be used or in general for the handling of dual-use species, an emission value should also be attached to the slaughter weight, as otherwise loopholes would arise and the meat of supposed dairy cows and laying hens would pass by emissions trading. If dairies, slaughterhouses, and egg producers/ first buyers are chosen as the regulatory point, animal products for personal use that are not sold would not be covered by emissions trading. However, this concerns very small quantities. Special attention should, however, be paid to preventing illegal slaughter and compliance with legal standards for domestic slaughter. At the same time, this would make it possible to link up with processing or supply companies (instead of with animal farmers) and thus generate a much smaller, more easily sizeable number of norm addressees. This way—also in view of the lower transaction costs—enforcement deficits and problems of depicting are minimised and the motivational situation of the parties involved is more accurately taken into account. Furthermore, advantages from an animal welfare point of view were noted without this being considered in more detail here. Regional output-based indicators could—if the farm level cannot be controlled in this way—make animal husbandry more attractive in the EU regions where the lowest emission values per animal or kilogram of product are determined [19] (p. 20), [89] (p. 13). Often, existing data could be used for this purpose.

The idea of the New Zealand model to integrate fertiliser manufacturers as regulatory points for emissions trading [19] (p. 11) is not pursued further in this paper. One reason is that the production of mineral fertilisers would already be restricted by a cap on fossil fuels, as mineral fertilisers can only be produced with renewable energies at significantly higher costs [21] (p. 329), [111]. Another reason is that N_2O emissions from the use of N fertilisers can be included by approximation in the general emission value or emission recording at farm level.

However, it is crucially important to introduce border adjustment measures as complementary tool of a cap-and-trade system in animal husbandry. Without such measures, the intra-EU demand for animal products would be replaced by production outside Europe. The ecologically and economically equal danger of spatial shifting effects is repeatedly pointed out in connection with one-sided climate protection efforts [15,19,57,88–90], [112] (p. 29). One solution for such a border adjustment is that importers of animal products must also obtain certificates. The proceeds from this "eco-duty" or these certificates could be made available at least partially for climate protection measures in developing countries given that they become part of the cap-and-trade system (more on this in [15]). In return, animal products could possibly be (partially) exempted from the certificate price when exported from the EU in order to put them on an equal footing with international competitors even though this would indirectly promote exports. An alternative is to assume marginal cost compensation with a conservatively measured general value that roughly corresponds to the price difference resulting from emissions trading cost savings. In general, these actions are feasible under world trade law, as has been examined in more detail elsewhere [15,113].

The approach proposed here would trigger a profound change in the livestock sector. Cattle farming is by far the EU's most polluting sector within livestock farming [38] (p. 23), [30] (p. 5), [57] (p. 188). It will therefore also be affected the hardest by a cap-and-trade system [112] (p. 59). This also becomes apparent at the level of emission intensity per kilogram of product, since beef is much more emission-intensive than pork or chicken [30] (p. 3). Under a cap-and-trade scheme for livestock farming, an internal shifting effect in favour of chicken and pig farming and at the expense of cattle farming (at least in relative terms) can therefore be expected, as the certificate price for beef per kilogram will be higher than for pork or poultry [80] (p. 173). Moreover, if the livestock farmers themselves do not have to purchase the certificates, this does not mean that they will react less or not at all to cap-and-trade, since the price signal from the cap-and-trade system has an effect on the entire production chain – irrespective of where the point of regulation is located within the chain [15], [19] (p. 20), [98] (p. 111).

An ecologically effective cap-and-trade system would therefore be based on the one hand, on the manufacturing industry as the regulatory point for trading certificates and, on the other hand, on average values of emissions per animal or kilogram of product, considering also the type of farming (e.g., grazing). This would at the same time address the topic of animal feed and possible changes in land use. Differing reduction potentials at farm level, which are not covered by the emissions trading system, could be additionally addressed by subsidies through the EU Common Agricultural Policy. If climate regulation by means of cap-and-trade systems for fossil fuels and livestock products is to be understood as an introduction to comprehensively sustainable agriculture, it could also be combined with a cap on pesticides (which are particularly problematic in terms of biodiversity), without it being possible to take a closer look at this here. However, the GHG regulation of animal husbandry alone may not be sufficient to protect and restore biological diversity. It is to be expected that the reduction in the number of animals will mitigate other environmental problems as well as the reduction in GHG emissions in line with the Paris climate objective, such as the impact of agricultural fertilisers. The regional concentration of livestock farming would also be somewhat reduced by the decarbonisation of the transport system through rising costs for feed, manure, and animal transport. Nevertheless, in addition to the examples of mitigation at farm level and pesticide cap, additional instruments may be needed to prevent local N and P surpluses [18,20,21]. Furthermore, despite the indirect addressing of land use changes and feedstuffs, some special sectors of emissions must also be considered – at least from special land use areas such as wetlands that are particularly important for GHG sequestration, which must therefore be protected and rewetted as far as possible [15,20,21], [75] (p. 36).

4.3. Climate-Linked Livestock-to-Land Ratio in Livestock Farming—in View of the EU Nitrate Directive and the Regulation on EU Organic Farming

When thinking about limiting the number of animals in order to achieve sustainability goals based on Article 2 PA (or the Convention on Biological Diversity), there is the other option of linking the number of animals to the available agricultural land, which also has the effect of limiting the absolute quantity. Such a livestock-to-land ratio could at the same time address the issue of disrupted nutrient cycles and partly also biodiversity losses [18] (pp. 365–372). In the following section, we will therefore assess how ecologically effective this alternative approach is (in detail see [22]). In the following Section 5, a final consideration is given as to which approach might be preferred, possibly also a combination of both approaches.

The currently observed decoupling of land and livestock in modern agriculture, which has progressed with the increase in productivity and specialisation of farms, is linked to numerous sustainability problems in animal husbandry [12] (p. 26,65), [18,20]. The acquisition of feed from external sources requires the use of fossil fuels for transport; feed imports from South America often cause land use changes for feed cultivation with significant consequences for global warming and biodiversity. Livestock-intensive regions that depend on feed purchases often show nutrient surpluses polluting soil, water, and air. Farms which specialise in fodder cultivation, in turn, have no access to farmyard fertiliser and use mineral fertilisers, whose production is energy-intensive and which, when used exclusively, contribute to soil degradation [17] (pp. 101–105). Therefore, the demand at hand is to re-establish the link between livestock and land and to promote farms that combine plant and animal production [20], [17] (pp. 101–105), [18] (pp. 365–372), [36,114].

In general, a livestock-to-land ratio (Flächenbindung) is defined as a limitation of the number of animals per hectare [21] (p. 330), [79] (p. 26) or a maximum amount of nutrients from manure that may be applied annually per hectare [18] (pp. 365–372) [115] (p. 19). However, the nutrient application ceilings do not automatically limit the number of animals per land on the same farm if manure can be transported to other regions [116] (p. 158). There is also no requirement for the minimum cultivation of animal feed on a farm. A livestock-to-land ratio in the strictest sense, which is most closely linked to the idea of closed nutrient cycles, would be given if the excrements of the animals were used to fertilise the cultivated areas of their feed [18] (pp. 365–372), [79] (p. 26). It therefore makes sense to require livestock farms to have sufficient arable land available to produce their own feed. This concept, which by definition is initially very rigid, can be softened by producing only a certain percentage of the feed on the farm itself, by allowing feed to be grown on neighbouring farms or within a specific region and by allowing surplus manure to be passed on to other farms.

The EU Nitrates Directive [60] currently provides for an EU legal maximum application limit of 170 kg N/ha/a from manure in areas at risk of nitrates. However, justified deviations are possible as long as the objectives of the Nitrates Directive are complied with and the deviation is based on objective criteria (e.g., long growth phases or increased N requirement of plants; Annex III No. 2 Nitrates Directive). According to Annex III No. 3 of the Nitrates Directive, Member States may calculate the application rates on the basis of animal numbers. This, theoretically, results in an upper limit of livestock per area. The Nitrates Directive, however, does not result in a livestock-to-land ratio in the stricter sense, especially as the regulation only applies to areas recognised as nitrate-endangered by the Member States. Even though some states apply their action programmes including the application ceiling of 170 kg N per hectare to the entire agricultural land, this currently only affects 61% of the EU's agricultural land [48] (p. 10). In addition, it is allowed for surplus manure to be moved to other regions or processed, so that the number of animals can only be limited if the transport of surplus manure over long distances becomes unprofitable and if there are no infringements. In addition, there are no requirements for on-farm cultivation of animal feed [18] (pp. 365–372) and deviations from the application limit can be approved [48] (p. 13).

A more binding requirement for a livestock-to-land ratio at EU level is laid out in the EU Organic Agriculture Regulation [117]—but only for farms voluntarily committing to organic standards. Livestock farmers who want to produce organic products must either have sufficient land themselves to spread their livestock's manure or have corresponding agreements with other organic farms that will spread the surplus manure on their land (Article 15 paragraph 1 in conjunction with Article 3 paragraph 3 of Regulation (EC) No 889/2008 [118]). As under the Nitrates Directive, the maximum annual application limit for N is 170 kg N per hectare (Article 3 paragraph 2 and Article 15 paragraph 1 Regulation (EC) No. 889/2008), which, however, must be adhered to in relation to area and not merely in terms of the average farm size [116] (pp. 290–292), [119] (p. 256). Annex IV to Regulation (EC) No 889/2008 derives from this the maximum number of animals permitted per hectare (e.g., two dairy cows per hectare). Alternatively, the animal stocking density can also be defined by national provisions which result from the Nitrates Directive (Article 15 paragraph 2 Regulation (EC) No 889/2008). In the new Organic Agriculture Regulation (EU) No. 2018/848 [120], which enters into force in 2021, the same application limit for N is maintained, but the resulting equivalence of the number of animals per hectare is omitted. Instead, the competent authorities are responsible for determining the livestock units corresponding to the limit value (Annex II Part II 1.6.6 and 1.6.7 Regulation (EU) No. 848/2018). With regard to the N application limit, the current and forthcoming Organic Agriculture Regulation is hardly stricter than the requirements of the Nitrates Directive, as they both refer to the same limit of 170 kg N from manure per hectare per year. The livestock-to-land ratio of the Organic Agriculture Regulation is more restrictive in that the upper limit applies to land and not just to farms, exceptions such as those provided for in the Nitrates Directive are not admissible and in that it must be complied with irrespective of whether the area or the farm is located in a nitrate-endangered area.

Another element of the livestock-to-land ratio of the Organic Agriculture Regulation in addition to the limited application of N, however, is the minimum requirement of on-farm production. If possible, at least 60% of the feed for herbivores and at least 20% for poultry and pork must come from the own farm or from other organic farms (Article 19 Regulation (EG) Nr. 889/2008, changed by Implementing Regulation (EU) Nr. 505/2012 [121]). According to Annex II Part II No. 1.4.1 of the new Organic Agriculture Regulation (EU) No. 848/2018, feed must mainly be grown on the farm where the animals are kept or on organic farms in the region. For both the old and the new wording, the interpretation of the word "region", in the absence of an EU-wide legal definition, varies widely between Member States. It ranges from medium-sized regions (Nomenclature of Territorial Units for Statistics—NUTS 2 of official statistics) to national, EU and global. The link between animal husbandry and animal feed cultivation is, especially in the last interpretation, not given [122] (p. 81).

Now that the existing EU regulations on the ratio of animal numbers to land area have been presented, the question is how a livestock-to-land ratio should be structured at EU level so that livestock farming is in line with the Paris climate objective. As far as legislative competence is concerned, a regulatory law provision on land use planning, for example a new regulation to be introduced, could be based on Article 192 TFEU. An obvious consideration would be to extend existing provisions on livestock-to-land ratios under the Nitrates Directive or the European Organic Agriculture Regulation to all agricultural land in the EU [79] (p. 27). However, this does not seem to do justice to the extent of the problem. According to the EU Nitrate Report, the average livestock density in the EU in 2013 is 0.73 livestock units per hectare of agricultural land (LU/ha)—with significant regional differences between the maximum value of 3.57 LU/ha in the Netherlands and the lowest value of 0.21 LU/ha in Bulgaria [48] (p. 3). First of all, it is noticeable that the average livestock stocking in the EU is well below the 2 livestock units per hectare permitted under the European Organic Agriculture Regulation (Annex IV of Regulation (EC) No 889/2008). The comprehensive application of a "2 LU/ha regulation" would even allow a multiplication of the animal numbers in some regions [79] (p. 28). To meet the Paris climate objective, however, the number of animals must be significantly reduced overall.

This raises the question of how GHG emissions from livestock farming can be linked to livestock density. An emission limit for GHG from animal husbandry would be divided by the agricultural area of the EU, resulting in an emission limit per hectare, which in turn could be translated into livestock units per hectare. In contrast to the Nitrates Directive or the Organic Agriculture Regulation, the livestock-to-land ratio would then not relate to the N emissions of the animals, but to their climate footprint.

Consequently, the decision on which emission sources are taken into account when determining the climate footprint or the maximum permissible emissions per hectare is of key importance. This is because they respectively form the basis for the determination of the total emission limit permitted in the EU. Here, the same considerations apply as for an emissions trading system for GHG emissions from animal husbandry. Only those emission sources should be included which can be quantified with sufficient precision and which are not or cannot be regulated elsewhere in accordance with Article 2 paragraph 1 PA (such as CO_2 emissions from the use of fossil fuels).

Also, there are various options for determining the emission standard per hectare as assessment basis for emission certificates. An emission standard per hectare is ultimately an emission certificate which is linked to land and cannot be traded. The gradual reduction of the emission ceiling could be implemented by successively reducing the permissible stocking density or the permissible maximum emission quantity per hectare (analogous to the dynamic cap in emissions trading). Regarding the conflict between the accuracy of emission recording on the one hand and transaction costs on the other, it must be considered whether there should be EU-wide, national or regional emission standards per hectare which specify for livestock farmers how many animals or animal products they can keep or produce depending on the area of their land, or whether only the GHG emissions per hectare should be determined EU-wide and the emission intensity is determined at farm level.

The first output-based option corresponds to the definition of livestock units which is no longer based on feed requirements [102] but on the GHG emissions of the animals (including feed production and manure management) in order to compare the emission intensity of the different livestock species (hereinafter referred to as "climate-linked livestock units"). However, this approach (as one which uses output-based emission values of certificates based on animals or animal numbers) would create an incentive to increase animal productivity, which could give rise to animal welfare concerns. If it is specified how many animals (differentiated according to animal category) may be kept per hectare, it is in the economic interest of farmers to obtain the maximum yield from this number of animals.

To counteract this, the upper emission limit could instead be based on the yields of the animal products, so that instead of a climate-linked livestock unit per hectare a maximum yield of animal products per hectare in kilograms of product is defined. Both data on animal numbers and yields from animal husbandry are easily sizeable control variables. An EU-wide consistent climate-linked livestock unit or yield of animal product per hectare would be conceivable, based on the average European emission intensity of the animal categories or animal products. Irrespective of the location within the EU, the same maximum output of animal products or the same livestock density defined by the climate-linked livestock unit would apply. However, this would ignore the national and regional heterogeneity of the emission intensity of animal production [38] (p. 24). Therefore, similar to the Nitrates Directive, only the emission quantity per hectare could be prescribed on EU level. The number of animals or kilograms of animal products per hectare corresponding to this emission quantity can be determined using regional or national average conditions. However, the disadvantage of these still large average values is that they often ignore local conditions. It would therefore be more accurate to take into account the emission intensity at farm level. This loops back to the problem known from the cap-and-trade system, though: it leads to hardly manageable control efforts. The fact that the phase-out of fossil fuels would strongly support the desired change in animal husbandry is otherwise just as true for a climate-linked livestock-to-land ratio as it is for animal-based emissions trading [21] (p. 329).

As a positive side effect, the deconcentration of animal husbandry and thus also of manure would lead to less nutrient surpluses accumulating in the soil or entering water bodies and the atmosphere [12] (p. 65), [123]. However, the idea of a decarbonised agriculture with a climate-optimised number of livestock (if by a livestock-to-land ratio or a cap-and-trade system for animal husbandry) raises the question of sufficient nutrient supply. Because, if the number of animals falls and thus less manure is available and at the same time, as is already the case in organic farming, mineral fertiliser produced with fossil energy is phased out, nutrient requirements must be supplied otherwise in order to avoid yield drops per hectare [17] (pp. 176–182), [21]. The possible increase in agricultural land to compensate for yield losses per hectare will be further exacerbated by the cultivation of bioenergy crops for renewable energy production [18,20], [21] (p. 330). In addition to the reduced number of animals and decarbonised agriculture, farmers would therefore have to take measures to ensure an adequate supply of nutrients, e.g., through increased fertiliser efficiency, the use of the nutrient content available in the soil, green manure, crop rotation with legumes and the use of recycled phosphate fertilisers [17] (pp. 116–119), [18] (pp. 68–113), [21] (p. 320), [124–128]. The application ceiling of 170 kg/N/ha for agricultural fertilisers in the Nitrates Directive already raises frequent doubts as to whether sufficient plant nutrition can be guaranteed [129] (p. 151). That suggests that the comprehensive renunciation of fossil-based mineral fertilisers represents a challenge.

In principle, a climate-linked livestock-to-land ratio increases the urgency to switch to using fertilisers that fit in with the circular economy and that go beyond organic fertilisation. The recovery of nutrients from waste water and waste streams along the entire value chain is not only important for climate reasons. The above-mentioned dependence on imports of mining phosphate fertilisers and increasing Cd and U pollution also suggest an increase in the recycling of nutrients [18,20,130]. At the same time, nutrient hotspots can still not be completely avoided through a livestock-to-land ratio. From the point of view of nutrient management, depending on soil characteristics, an even lower livestock density than required by a livestock-to-land ratio may be preferable [18] (pp. 365–372). However, the probability of nutrient surpluses due to high livestock numbers is likely to be greatly reduced by an ambitious definition of the emission standard per hectare.

To prevent shifting effects of animal husbandry to non-EU countries which are detrimental to both the environment and the economy, a livestock-to-land ratio (just like a cap-and-trade system) would have to be supplemented by protective mechanisms at the external EU borders vis-à-vis countries that do not provide for similar regulations [21]. In contrast to the integration of non-European processing and supply companies into a cap-and-trade system, this would require more than simply having them buy certificates for certain products. Rather, requirements for foreign production – and in the event of non-compliance – import bans would have to be formulated (more detailed on World Trade Organization (WTO) law [81,113,131,132]. Furthermore, there is a need for a supplementary regulation to both livestock-to-land ratio and cap-and-trade for pesticides and at least for certain land use changes, e.g., regarding peatlands.

5. Discussion

To examine the question of whether a cap-and-trade system for GHG from livestock farming or a climate-linked livestock-to-land ratio would be preferable as the main instrument of sustainability governance of livestock farming in the EU, they are now compared in view of the objective of Article 2 paragraph 1 PA with additional consideration of further ecological problems. As announced, the motivational and governance problems introduced in Section 2 will be included. As already mentioned, the comparison is not based on empirical data, but on the structural characteristics of the instruments in the light of the objectives and typical governance problems – in the absence of the existence of these systems.

Both instruments are based on a limit for GHG emissions from animal husbandry, which need to be defined considering the existing sink potentials in a way as to ensure that the Paris climate objective (Article 2 paragraph 1 PA) is achieved. Both instruments allow for successively reducing the emission ceiling, either by reducing the number of certificates in line with the cap or by reducing the permissible emissions per hectare from livestock farming. This shows that both approaches can serve as instruments of quantity governance, although a livestock-to-land ratio could be classified as "regulatory law" (but without being focused only on individual actions, plants, or products) and emissions trading would be seen as "economic instrument" (despite the fact that the binding cap could also be called "regulatory").

In relation to hotspots in the event of nutrient surpluses and in relation to biodiversity losses, both instruments pave the way in various ways. The livestock-to-land ratio sets the limit even more directly. However, the capacity of a livestock-to-land ratio to avoid local nutrient surpluses also depends on its precise design. In addition to the maximum livestock density resulting from the emission standard, the decision as to whether the stocking density is to be maintained at farm level or whether land outside the farm can be used also plays a central role. The decisive factor for the target stringency is whether the farmyard manure of the livestock farm must then be distributed to all of these land areas or whether nutrient application is additionally limited per hectare.

Rebound effects could occur in the production of animal food if the emission intensity or the environmental impact of production per production unit (e.g., per kilogram of animal product) decreases, but overall production increases, thereby reducing the positive environmental effect or even increasing the absolute impact. It is conceivable that by exploiting the technical mitigation potential, the emission intensity of animal products will decrease, and thus more animal products can be produced while the emission maximum persists. However, since both governance instruments presented provide for an absolute cap on emissions, rebound effects that exceed the specified maximum emission of GHG from animal husbandry can be ruled out.

Regarding the possible danger of shifting effects, a cap-and-trade system and a livestock-to-land ratio appear to be largely similar at first glance. Consumers will compensate for the shortage and the raised prices of animal foodstuffs by consuming more plant products, aquacultures, meat substitutes and, in future, possibly artificial meat and insects. Among the animal products, the price signal is used to switch to less emission-intensive products, for example from beef to pork and poultry or from meat to dairy products and eggs. These shifts in consumption are a desired effect of the sustainability instruments, while the decisive factor for the ecological advantage is that the substitute products are produced with lower emissions than the replaced products thus avoiding a sectoral shift in emissions. This were a possibility if a cap on fossil fuels did not simultaneously raise the price on other energy-intensive products as well for their climate footprint, e.g., frozen goods, air-freighted fruit (which underlines again the need for a combined quantity governance for fossil fuels and livestock products). For plant-based products in general, however, apart from possible processing, cooling and transport emissions, there is no danger of sectoral emission shifts, since their production is significantly lower in emissions [4–8].

A shift to increasing other environmental problems could occur if the substitute products require more of other resources such as land or water, but this can also be ruled out for plant products. Resource-related shifting effects can, however, arise from technical measures to reduce emissions in animal husbandry. For example, increases in productivity in feed production can reduce the intensity of GHG emissions and prevent the expansion of farmland [27] (p. 455), but can conflict with other environmental problems such as disrupted nutrient cycles, biodiversity loss and the use of agrochemicals [2], [74] (p. 3). Indirect shifts to other environmental problems can be expected through the subsequent use of the released land, which previously served for fodder cultivation or as grazing land. As part of the decarbonisation of the entire economy, it is very likely that bioenergy plants will be cultivated more intensively, which could, however, be avoided by regulatory measures or by pricing land use [15,18,20].

The danger of an increase in emissions from livestock farming through spatial shifting within the EU is largely averted by the EU-wide cap or the EU-wide livestock-to-land ratio. The production of animal food products will probably relocate within the EU, especially with regard to a livestock-to-land ratio, but EU-wide emissions (assuming effective implementation) will not exceed the defined maximum. Here, again, it must be stated that a cap-and-trade system and a livestock-to-land ratio can be very similar, depending on the design. This is particularly the case when a cap-and-trade system, based on the emissions of animal products at regional level, is compared with a livestock-to-land ratio which also uses regional averages instead of data on individual farms.

However, there are four aspects that advise against using a livestock-to-land ratio as the main climate policy instrument for regulating emissions from the livestock sector:

- Both instruments face the challenge of the diversity of emission sources in animal husbandry and of the high number of animal farmers. This complexity can best be reduced with a cap-and-trade system. The implementation-related advantage of an emissions trading system over a climate-linked livestock-to-land ratio is that there is the option of choosing the manufacturing industry as the norm addressee instead of the animal husbandry plants, by choosing animal products as the subject of the emissions trading certificates. If emissions are determined at farm level, all information provided by livestock farmers (far more numerous than the manufacturing industries) would have to be checked for accuracy. For this reason, a cap-and-trade system offers a cost and control advantage over a climate-linked livestock-to-land ratio under regulatory law which makes compliance with standards and, moreover, the political enforceability of the instrument more likely.
- Cap-and-trade has less impact on livestock farmers than a climate-linked livestock-to-land ratio. Livestock farms are more restricted in their development due to the land-link than is the case with a cap-and-trade system, even if the total emission maximum on EU level is the same for both instruments. The introduction of a climate-linked livestock-to-land ratio would imply greater structural adjustments in line with the deconcentrating of livestock farming, which may result in high investment costs for the construction of new farms and facilities for the livestock farmers. The costs would far exceed those of buying additional certificates for keeping the same amount of livestock in existing, just (in total) shrinking structures.
- If a livestock-to-land ratio is the main instrument, complementary import bans are necessary, since this instrument (unlike ETS) cannot be combined with a border adjustment. However, such import bans may not be justifiable under world trade law. This is due to the fact that—unlike in a cap-and-trade system—there is no direct link to a product, namely animal food. Rather, standards would have to be placed on the production methods of those products abroad. Standards like that—e.g., via Article XX General Agreement on Tariffs and Trade (GATT), which allows ecologically justified exceptions to the free trade rules of the WTO—have repeatedly been

advocated legally (e.g., [113,133]. The WTO courts are so far very hesitant about allowing for such production-related regulations, in contrast to product-related regulations, however (for more details on border tax adjustments in the environmental sector, see [15,18,81,113,132,134]).

- Regarding biodiversity conservation and closed nutrient cycles, the climate-linked livestock-to-land ratio has the advantage of indirectly limiting animal N and P surpluses by limiting GHG emissions per hectare. However, this advantage is particularly evident only if the stricter and more inflexible design of a livestock-to-land ratio is chosen that does not allow for using off-farm areas and/or adds nutrient restrictions per hectare. At the same time, it should be remembered that a cap-and-trade system for animal products also indirectly addresses other environmental problems as described above. Furthermore, the gradual phasing out of using fossil fuels in the economy as a whole is already providing impetus for more land-linked animal husbandry such as pasture farming: the purchase of animal feed, the production of mineral fertilisers, the transport of farm fertilisers and the transport of animal products will become more expensive due to a strict cap on fossil fuels, thus favouring decentralised animal husbandry. In addition, the EU-wide emission ceiling will also reduce the number of livestock in absolute terms, so that the problem of nutrient surpluses will be alleviated overall.

To counter any potentially remaining hotspot problems of nutrient surpluses from regionally concentrated intensive animal husbandry, a cap-and-trade system would, as mentioned, possibly require complementary regulation. This could consist of a livestock-to-land ratio at farm level, which only provides a moderate upper cap, and thereby delivers the necessary governance input in terms of biodiversity and deconcentration of animal husbandry without a need address the exact amount of GHG emissions, therefore being more easily enforceable. The combination of both instruments would render all further specifications on nutrient loads superfluous, with the exception of hazard-prevention regulations on pollutants in fertilisers, for example, or specifications on the recycling of sewage sludge, which would continue to be necessary in addition to the regulatory provisions [15,18]. As mentioned before, it stands to reason that with regard to bioenergy and at least to certain land use changes, e.g., for wetlands, additional regulations can be placed in regulatory law as well as in the general pricing of land use [15,18,135]. Maybe, the question of additional import regulation for animal feed will raise further debates in the future, since animal feed imported from South America in particular is associated with direct and indirect land-use changes, which have serious consequences for biodiversity, soil, and climate [20]. However, as said before, it is rather questionable to what extent this would hold up legally under WTO law. Either way, in addition to the governance approach developed here, the EU agricultural subsidies, which largely provide contrary incentives, would have to be fundamentally changed or possibly abolished altogether. Details of the EU subsidies are left to be discussed elsewhere.

6. Conclusions

The starting point of this paper was an empirical analysis showing that the production of animal food products is (besides fossil fuels) one of the most important noxae with regard to many of the environmental problems, such as climate change, biodiversity loss, or globally disrupted nutrient cycles. This contribution provides a qualitative governance analysis of the effectiveness of possible economic policy instruments for livestock products, measured against legally binding objectives especially from international climate law and international biodiversity law. Taking into account findings from behavioural sciences and typical governance problems, the major focus is on a transnational cap-and-trade scheme for livestock products (and fossil fuels). In comparison with a climate-linked livestock-to-land ratio, it is demonstrated that—while both instruments are suitable to the cause—this is a cost-efficient and control effective legal solution, also taking the legal framework of international trade into account. By the same token, it was shown that the combination of such a differentiated cap-and-trade-system for livestock products combined with a biodiversity-oriented (not climate-oriented) livestock-to-land ratio at farm level is an even better option, since it is able to address various environmental issues associated with livestock farming at the same time. As a result, extensive and low-emission livestock farming would be incentivised (including innovation regarding respective practices), while emission-intensive livestock farming systems will be hardly viable anymore. All of this simultaneously demonstrates, on the basis of a rarely considered but ecologically highly relevant sector, how a quantity governance approach that is based on an easily comprehensible governance unit can function across all sectors and regions.

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