agriculture

MDPI

Review

Sustainable Livestock Production in Nepal: A Focus on Animal Nutrition Strategies

Prabhat Khanal [1,*], Rajan Dhakal [2], Tanka Khanal [3], Deepak Pandey [1], Naba Raj Devkota [4] and Mette Olaf Nielsen [5]

[1] Animal Science, Production and Welfare Division, Faculty of Biosciences and Aquaculture, Nord University, Kongens Gate 42, 7713 Steinkjer, Norway; deepak.pandey@nord.no
[2] Department of Veterinary and Animal Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, 1870 Frederiksberg, Denmark; dhakal@sund.ku.dk
[3] Grand Valley Fortifiers, 151 Savage Dr., Cambridge, ON N1T 1S6, Canada; tankakhanal@grandvalley.com
[4] Vice Chancellor Office, Gandaki University, Gandaki, Pokhara 33700, Nepal; nabadevkota.gandaki@gmail.com
[5] Department of Animal Science, Aarhus University, 8830 Tjele, Denmark; mon@anis.au.dk
* Correspondence: prabhat.khanal@nord.no; Tel.: +47-74112129

Abstract: In many developing countries, the livestock sector plays a vital role in the national economy, providing a source of food, income, and employment. With changes in demographical, socio-economic, and environmental status, the livestock sector in the developing world is facing challenges of low productivity and has become both a culprit and a victim of undesirable climate change impacts globally. In this paper, we will review the status of Nepalese livestock production systems and evaluate possible livestock species-specific strategies to promote a more productive and sustainable livestock sector in the future. In Nepal, the livestock sector is deemed essential to alleviate poverty and improve the nutritional status of the population, as in many other developing countries. However, there is a need for substantial improvements in livestock productivity, in particular improvement of feeding strategies to exploit the genetic potential of livestock. For ruminants, the important issue is to improve nutritional value and hence utilization of existing feedstuffs. Use of, e.g., urea, molasses, and enzymes to improve feed digestibility and implementation of technologies to effectively preserve biomass from forages that are only seasonally available are necessary strategic measures. Identification and use of novel anti-methanogenic feed ingredients will be crucial to develop a ruminant livestock sector that is not only productive, but also environmentally sustainable. For monogastric animals, the development and use of novel protein feed ingredients, such as insects raised on indigestible (for monogastrics) plant residues, should become part of future feeding strategies in support of a circular bioeconomy and improved productivity, not least in small scale poultry production. Future policies should also include a strong focus on capacity building and development of research infrastructure, and promotion of collaborative activities among research and industry sectors to establish a productive yet sustainable livestock sector in Nepal.

Keywords: environment; feed resources; livestock productivity; policy; sustainability

Citation: Khanal, P.; Dhakal, R.; Khanal, T.; Pandey, D.; Devkota, N.R.; Nielsen, M.O. Sustainable Livestock Production in Nepal: A Focus on Animal Nutrition Strategies. *Agriculture* **2022**, *12*, 679. https://doi.org/10.3390/agriculture12050679

Academic Editors: Lubomira Gresakova and Emilio Sabia

Received: 22 February 2022
Accepted: 3 May 2022
Published: 10 May 2022

1. Background

Globally, the livestock sector is a principal source of food and employment. It is one of the fastest-growing agricultural sub-sectors, which provides livelihoods for ~1.3 billion people and accounts for ~40% of the global agricultural gross domestic product (AGDP) [1]. The livestock sector is expected to become even more crucial in the future, particularly in light of a rising human population, which is estimated to become ~9.7 billion in 2050 [2]. In this respect, the livestock sector will play a vital role in fulfilling a growing demand for animal-derived foods [3], while ensuring future global food security [4].

The livestock sector and the production of animal-derived foods are, however, also significant contributors to climate change. The livestock sector alone represents about ~18% of total anthropogenic greenhouse gas (GHG) emissions in the world [5]. There is an unfortunate association between the fermentation of feeds in the forestomach of ruminant animals and the enteric formation of the potent GHG, methane [6]. Growing concerns on the impacts of the livestock sector on environmental health have posed severe challenges to this sector, and there is increasing pressure for GHG mitigation from environmentalists, consumers, and policymakers, both locally and globally [7]. Thus, it is a primary issue for the livestock sector today to develop sustainable production systems, where animal-derived food can be produced with increased efficiency to accommodate growing demands from an increased human population, at the same time as impacts on the environment need to be decreased [8].

In the developing world, including Nepal and other Asian regions, livestock is a primary source of major dietary nutrients and a critical component of small-scale crop–livestock mixed farming systems [9]. The demand for livestock products is projected to increase in developing regions due to a rise in urbanization and income levels [10]. In addition, developing countries are predicted to contribute a significant part (up to 97%) of the global population rise [11], and the population of the developing world alone will reach 7.6 billion by 2050 [12]. Today, the livestock sectors in developing nations are facing two major challenges. Firstly, low animal productivity remains a significant problem, although some tendencies are seen towards scaling up production levels, mainly for monogastrics [13,14]. Secondly, livestock in developing nations accounts for 50–65% of the global GHG emissions from the livestock sector [10], thus contributing to climate change and global warming. However, there are a relatively limited number of studies evaluating the status of animal production in the developing world, particularly in very low-income countries, which limits our insight into the necessary measures to expand productivity at a lower environmental cost in the future. In this context, this paper aims to evaluate the current status of livestock production in Nepal to identify potential strategies that could be employed in the future to establish a more sustainable development of the livestock production systems, whilst considering the prevailing socio-economic conditions. We believe that the issues put forward here would also be relevant for other low-income countries with similar agro-climatic situations, which face a similar challenge with respect to the sustainable development of livestock production in the future.

2. Methodology

To evaluate the current status, identify key constraints, and elaborate suggestions for future policies to promote the development of the Nepalese livestock sector, we reviewed the limited body of available scientific publications related to Nepalese livestock production, animal nutrition, and livestock policies. To search peer-reviewed articles, databases such as Google Scholar, Web of Science, Agricola, Agricultural and Environmental Science Database, Agris, CAB, and Abstracts were used. Different keywords and search terms including "Feed resources" and "Livestock" and "Productivity" and "Sustainability," and "Nepal" were included as search terms. In addition, various reports and databases published by the Ministry of Agriculture and Livestock Development, Nepal (https://www.moald.gov.np/publication/Agriculture%20Statistics assessed on 6 December 2021); Central Bureau of Statistics, Nepal (https://cbs.gov.np/metadata/; assessed on 6 December 2021); National Population and Housing Census, Nepal (https://censusnepal.cbs.gov.np/Home/Index/EN; assessed on 6 December 2021); and the statistical database of FAOSTAT (https://www.fao.org/faostat/en/#data; assessed on 6 December 2021) were also used. All graphs were generated using GraphPad Prism software 7.0 (San Diego, CA, USA).

2.1. Data and Calculations Underlying Projections for Milk Production and Demands

We analyzed the trend of annual milk production compared to demand using data from the Nepalese ministry [15,16]. We calculated the current milk demand (ton/day)

using the FAO recommendations of 320 mL/day of milk or dairy products for adults (>18 years of age) for Nepal [17]. The values for daily milk demand would be even higher if they were corrected for the needs of non-breast-fed infants and children and teenagers below 18 years of age, who have a daily recommendation of 500 mL/person/day [17]. In addition, we made future projections of daily milk demands (ton/day) in Nepal for the period 2020–2030. The calculations for the projection of future demands were performed based on the projected increase in the total population of Nepal during that period, as presented by CBS [18], and the expected minimum demand for milk based on the FAO recommendations for daily milk consumption (320 mL/adult/day) for adults (>18 years of age) from developing countries [17].

2.2. Data and Calculations Underlying Projections for Meat Production and Demand

Projecting the future trends in annual meat production compared to demand was conducted in a similar way, using data from the Nepalese ministry [15,16]. The total annual meat production was calculated based on the amount of meat from major meat-producing animals, and also included the amount of duck meat which is negligible (217–281 tons/year) compared with other livestock species. The meat demand was calculated based on the FAO data for average meat consumption per capita (27.9 kg/person/year or 76.4 gm/person/day) in the developing countries [4]. We further made pessimistic projections for future meat demands in Nepal based on the FAO data for average annual meat consumption per capita for developing countries. Three separate projections were made based on the average annual meat consumption per capita for developing countries, worldwide population, and developed countries: 27.9 kg (76.4 gm/person/day), 38.7 kg (106 gm/person/day), and 80 kg (219.3 gm/person/day), respectively [4].

3. Nepalese Livestock Production

Nepal is an agricultural land-locked country situated in South Asia between India and China [19], where the agricultural sector is the prime source of national income, and it contributes about 32% to national gross domestic production (GDP), involving ~65% of the economically active population [20]. Nepal consists of high mountains, the Himalayan range (35% of total area), mid-hilly regions (42% of total area), and the lower plain of the Terai region (23% of total area) [20], each characterized by very distinct agro-climatic conditions. Thus, the Nepalese agricultural sector has regional and very distinct resource-use patterns from the lower plain areas bordering India (Terai region) to the Himalayan area at around 5000 m altitude near the Tibetan region.

Livestock is an important sub-sector within the Nepalese agricultural sector and accounts for ~25% of the national agricultural GDP [21]. The domestic livestock production in Nepal is based on 17 different species [22], which encompasses buffalo, cattle, goats, sheep, pigs, and poultry as the main farm animals (Figure 1), accounting for a total annual milk and meat production of 1,911,239 and 332,544 tons, respectively [20]. One of the critical features of Nepalese livestock is the subsistence nature of farming, where typically, a single household manages only a small number of animals. Accordingly, the Nepalese agriculture census defines the economic unit of an agricultural holding in terms of livestock production as at least one big head (cow, buffalo, etc.) or at least five small heads (goat, sheep, etc.) or poultry consisting of at least 20 birds (chicken, duck, etc.) managed under a single management system [23]. Farmers generally raise their few animals alongside other agricultural components, such as agronomical crops, fruits, or vegetables, and the animals are either kept in a shed or allowed to graze or scavenge freely during some hours of the day. In recent years, the number of commercial dairies (cow, buffalo), pig and poultry farms has been growing in Nepal; however, overcoming low livestock productivity is one of the significant challenges [24], as described in the following.

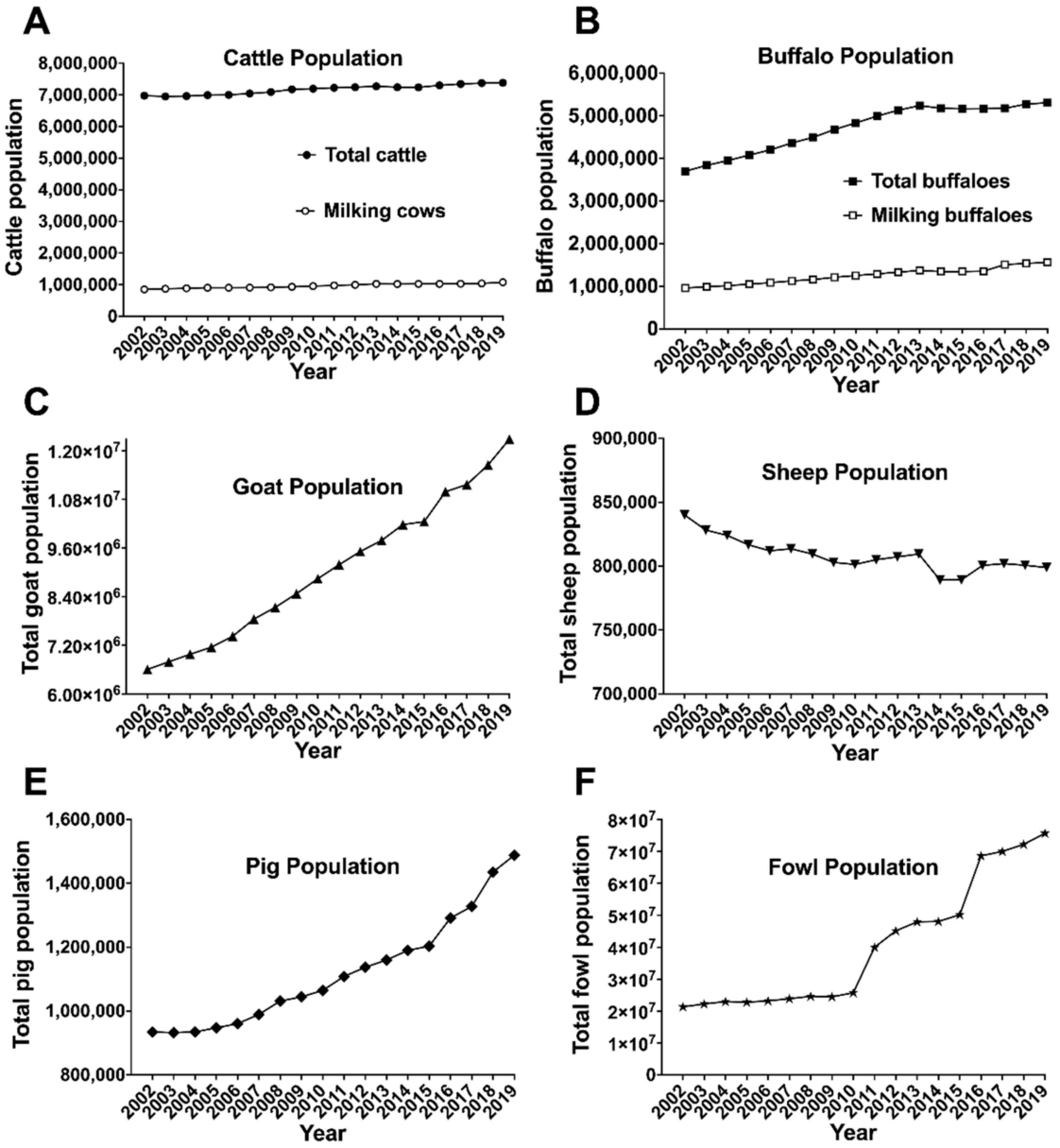

Figure 1. Population trend of major livestock species in Nepal from 2002 to 2019 (MOALD, 2017; MOALD, 2019) [15,16]. (**A**): Population trend of cattle (solid line, ●: total number of cattle; solid line ○: number of milking cows), (**B**): Population trend of buffalo (solid line, ■: total number of buffalo; solid line, □: number of milking buffalo), (**C**): Population trend of goats, (**D**): Population trend of sheep, (**E**): Population trend of pigs, and (**F**): Population trend of fowl.

4. Current Status

In the following sections, the status of livestock production from various species in Nepal will be highlighted in relation to their number, management, and overall production status, and strategic concerns regarding improvements in productivity of the different livestock species will be addressed.

4.1. Major Milk-Producing Animals in Nepal

In Nepal, buffalo and cattle are the major milk-producing livestock species. In this section, we will review the status and identify constraints for the improvement of productivity of the various livestock production systems.

4.1.1. Cattle

Cow milk (665,285 tons annually) is the second primary source of liquid milk consumption after buffalo (1,245,954 tons annually) in Nepal, accounting for about one-third of the total milk production [20]. Despite the significant contribution of cattle to the Nepalese dairy sector, cow milk productivity is very low compared with the global average. Additionally, milk production trends are not promising as annual dairy cattle milk productivity in 2001 was 412 kg/milking cow, and it had only increased to 627 kg/milking cow by 2015 [20]. One crucial aspect in this respect is that non-milking cows share a substantial proportion of the total cattle number since milking cows represent only ~14% of the entire cattle population [20]. Due to religious issues, it is not possible to cull non-productive cattle in Nepal.

When formulating future policies to improve the national self-sufficiency for milk, it is, therefore, recommended to focus on other milk-producing animals, such as buffalo, goats, and in mountainous regions, even yak. In contrast to cattle, these different species are associated with fewer religious constraints, allowing for efficient breeding and culling policies to be implemented. Details of the milk production status of goats, sheep, and yak are not available, and thus, in the following, the milk production status of only buffalo will be presented. However, goats are particularly very suited to Nepal's mountainous agricultural zones and can contribute to the national milk production and the development of milk-based industries also for small-holders, provided suitable breeding and proper livestock management approaches are applied. More recently, goat milk has been recognized as a particularly efficient tool to fight against malnutrition in the ultra-poor population, and the government has introduced various programs to promote dairy goat farming among poor farmers.

4.1.2. Buffalo

Indigenous buffalo *(Bubalus bubalis bubalis)* are distributed from sub-tropical to alpine zones of Nepal. Buffaloes are the greatest source of milk and meat production (Figures 2 and 3), contributing significantly to the agricultural gross domestic product (AGDP). They are exploited mainly for milk and meat, and to some extent, for draft power and manure. A recent report suggests that buffalo alone contribute to >50% of total meat and >60% of total milk production in Nepal, as shown in Figures 2 and 3 [20].

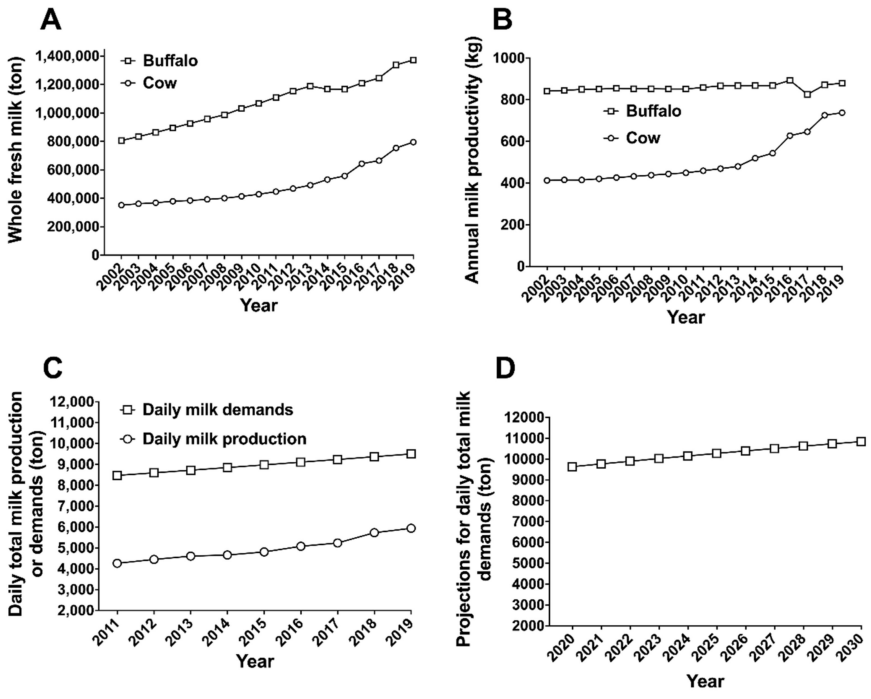

Figure 2. Status of milk production in Nepal (MOALD, 2017; MOALD, 2019) [15,16]. (**A**): Annual whole fresh milk production in ton for 2002–2016 (solid line, □: buffalo milk; solid line; ○: cow milk),

(**B**)**:** Annual milk productivity (kg/milking animal/year) of cow and buffalo for 2002–2016 (solid line, □: buffalo; solid line; ○: cow), (**C**): Status of annual milk production and demand (ton/day) in Nepal for 2011–2016 (solid line, □: daily milk demand; solid line; ○: daily milk production). The daily milk demand for Nepal was calculated using FAO recommendations of 320 mL/adult/day for adults (>18 years of age) [17]. The values for the daily milk demand would be even higher if they were corrected for the needs for non-breast-fed infants and children and teenagers below 18 years of age who have the daily demand of 500 mL/person/day [17]. (**D**): Projection of daily milk demand (ton/day) in Nepal for the period 2020–2030. The calculations for the projection were performed based on the projected total population of Nepal during that period presented by CBS [18] and the FAO recommendations for daily milk demand (320 mL/adult/day) for adults (>18 years of age) from developing countries [17]. The values for projected milk demands would be even higher if they were corrected as described in (**C**).

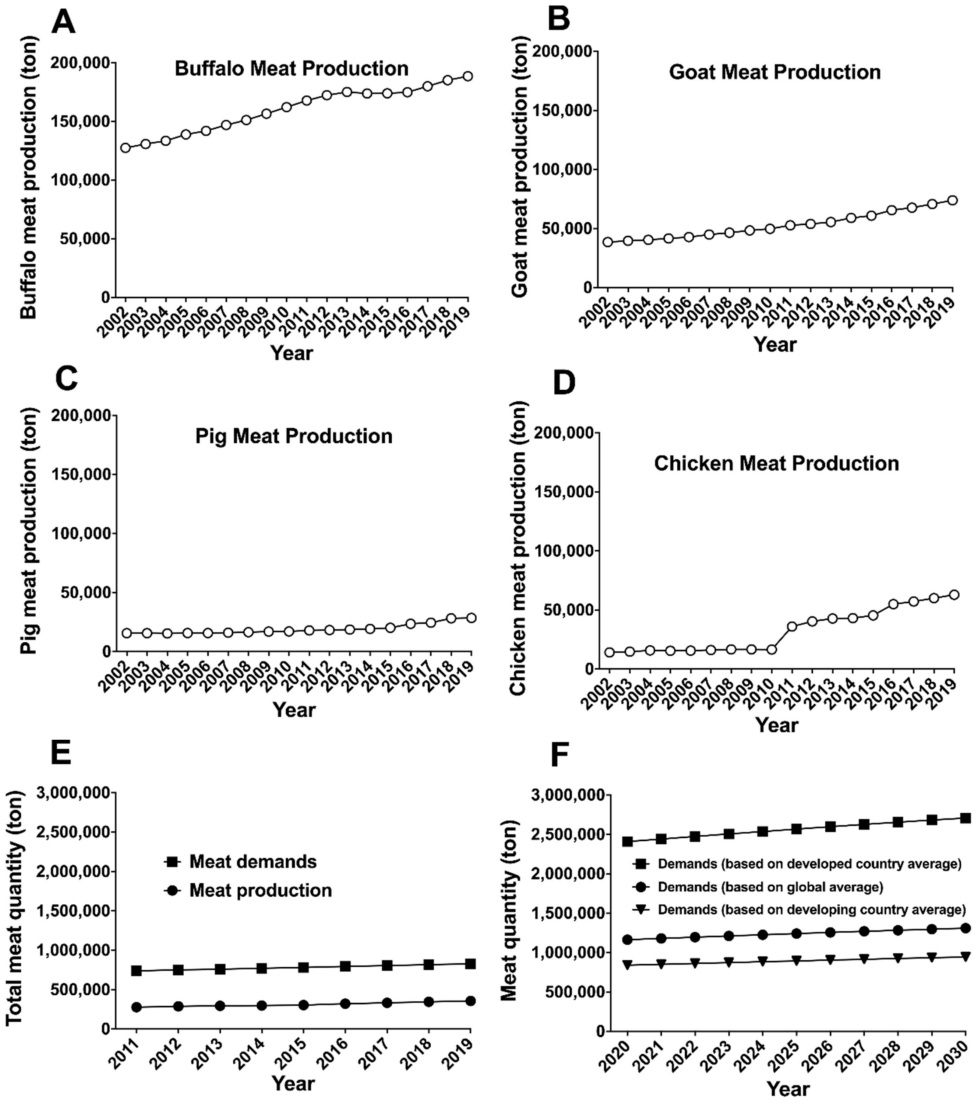

Figure 3. Status of meat production in Nepal (MOALD, 2017; MOALD, 2019) [15,16]. (**A**): The trend of total annual buffalo meat production (in ton) during the period 2002–2016, (**B**): The trend of yearly total goat meat production (in ton) for the period 2002–2016, (**C**): The trend of total annual pig meat production (in ton) during the period 2002–2016, (**D**): The trend of yearly total chicken meat production (in ton) during the period 2002–2016. (**E**): The trend of total annual meat production compared to demands for

2011–2016 in Nepal (solid line, ●: meat production; solid line, ■: meat demands). The total annual meat production was calculated based on the amounts of meat from major meat-producing animals and also included the amount of duck meat, which is negligible (217—281 ton/year) compared with other livestock species. The meat demands were calculated based on the FAO data for average meat consumption per capita (27.9 kg/person/year or 76.4 gm/person/day) in the developing countries [4]. (**F**): Projection for meat demands (in ton) during the period 2020–2030 based on the FAO data for average annual meat consumption per capita (solid line; ■: developed country and solid line; ●: global average, solid line; ▼: Nepal, developing country). The average annual meat consumptions per capita for developing countries, worldwide population, and developed countries, developing countries were used as 27.9 kg (76.4 gm/person/day), 38.7 kg (106 gm/person/day), and 80 kg (219.3 gm/person/day), respectively [4].

There are mainly three indigenous breeds of buffalo in Nepal: Lime, Parkote, and Gaddi, distributed predominantly in low hills, mid-hills, and far western hills, respectively [25]. However, imported breeds are becoming increasingly popular, with Murra now dominating current buffalo production among them. Low milk production (893 kg/milking buffalo) is a significant challenge in the buffalo production system, and realizing this, the Nepalese government launched the 20-year Agriculture Perspective Plan (APP) in 1995, where the priority was given to milk production. However, Nepal continues to import considerable amounts of whole milk and live buffalo from a neighboring country. To become self-sufficient in milk production, buffalo is the primary species to be targeted, and the focus should mainly be on buffalo milk productivity.

4.2. Major Meat-Producing Animals in Nepal

In Nepal, cattle do not contribute at all to national meat production as the consumption of meat from cattle and the use of cattle for meat production are prohibited for religious reasons. Therefore, buffalo, goat, sheep, pig, and poultry are the key sources of meat. In the following sections, the major constraints and possibilities for meat production from different livestock species will be presented.

4.2.1. Buffalo

In addition to a significant contribution to total milk production, buffalo are the major contributors to meat production in Nepal. Buffalo meat (cara or buff) accounts for nearly 60% of the national total meat consumption [20]. In general, male and unproductive female buffalo are slaughtered for meat consumption, whereas reproductive females are used for milk production. The female buffalo are mostly culled due to infertility, repeated breeding, and disease problems such as mastitis. With cultural transformation (relaxation of traditional norms and values for eating behaviors), so-called higher caste people like Brahmin have also started consuming cara meat in Nepal, thus increasing the overall demand for buffalo meat in recent decades. Additionally, cara meat is cheaper than other meat sources such as chevon, mutton, and chicken. Thus, in the future, it can be anticipated that the demand for buffalo meat will continue to increase, along with growing purchasing power among the lower strata in society. Therefore, it is recommended considerable strategic emphasis be placed on buffalo production to increase total meat production in the future.

4.2.2. Goat and Sheep

Small ruminants (goats and sheep) are vital components of farming systems in the developing world, and Asian countries account for about 57% and 23% of the world populations of goats and sheep, respectively [26]. In Nepal, goats are a crucial element of agricultural systems. Many farmers raise goats primarily for meat purposes (animal protein), and goats serve as an important source of income and savings in many rural families. Historically, goats have been well integrated into a typical crop–livestock mixed farming system, particularly in the hilly regions, due to their ability to capitalize available

plant biomass resources as feeds in mountain terrains. However, goats are also raised in the lower plain (Terai) regions of the country.

The total production of goat meat continues to grow in Nepal. Such an increase in production appears to be driven primarily by the rise in the population of goats, as recent trends indicate (Figures 1 and 3) [20], and to some extent also by improved feeding. It is estimated that goats contribute about 20% of the total Nepalese meat production. A large number of goats (~15% of the total population) is imported from India to fulfill the national demand for goat meat [27]. In Nepal, there are mainly four indigenous goat breeds: Chyangra, Sinhal, Khari, and Terai, where Khari is the predominant breed accounting for ~50% of the total goat population [28]. Although breed-specific production traits exist, all goat breeds generally have low productivity in Nepal, which is associated mainly with poor management practices. Chyangra and Sinhal are primarily found in the high hills and mountainous regions. They are managed under a migratory system, where animals graze alpine pasture areas during the summer months but are allowed to graze on the lower fallow crop fields and forests during periods of extreme winter conditions. Khari and Terai breeds are found primarily in the lower hills and Terai regions. Both of these breeds are generally managed under a sedentary system, where animals are allowed to graze for a few hours during the day in the nearby forest, fallow land, and pasture areas [28], complemented by feed brought to them in a cut-and-carry system. Several imported goat breeds are also being raised throughout the country, particularly Boer goats, which have become popular in recent times. In this context, the improvement of local indigenous breeds, the establishment of commercial farms with a higher stock density, and the introduction of proper nutritional strategies for sustained availability of feeding materials are the three key areas the Nepalese goat sector should focus on to improve the productivity of goats and fulfill the national demand for meat and milk from this species.

Sheep also constitute an important component of the Nepalese agricultural system, particularly in the Himalayan regions, where they serve as a source of meat, wool, and cash income. Most sheep in Nepal are reported to be of region-specific native breeds: Bhaynglung in the Transhimalaya, Baruwal in the mountains and Kage in the hills, and Lampuchhre in the Terai region. Nevertheless, sheep production is primarily limited to the upper Himalayan areas and adapted to the local climatic conditions, where sheep (like goats) are managed under a migratory or transhumant system. Sheep are well adapted to the local climatic conditions of the mountainous region with a diet primarily based on alpine pasture [29]. The sheep population and total sheep meat production have sharply declined in the past in Nepal (Figure 1 and Figure S1A) [20] which could, in part, be associated with the poor performance of local breeds, seasonal deficit of feed resources, and a lack of efficient market channels for sheep meat and wool [30]. Increased urbanization and migration of youth from villages to cities and abroad in search of employment may also have played a role. Since sheep are a crucial component of mountain agriculture, it is critical to develop efficient management and marketing strategies to establish a more profitable and sustainable livestock production, which can sustain a livelihood for people and encourage young people to reside in the high mountain regions, poorly suited for other agricultural activities.

4.2.3. Pigs

Pigs are one of the major livestock species in Nepal and are ranked as the 5th most important livestock species after fowl, cattle, buffalo, and goat in terms of population numbers. The trend for population size of pigs is increasing (Figure 1E) [15], and indigenous pig breeds contribute significantly (~50%) to the total pig population [31]. Due to certain cultural and religious taboos, pork production and consumption were limited to specific ethnic communities in the past. However, along with the transformation in cultural beliefs and values, pork has become a popular choice among the Nepalese, particularly in the urban areas, as evidenced by a sharp increase in pork production and consumption (Figure 3C) [15].

In the future, pork is expected to contribute substantially to the country's total meat production. With changing demands for pork, it is vital to conserve indigenous pig resources for future pig improvement programs [31]. Since the traditional small-scale subsistence piggery is mostly maintained under quite low planes of nutrition, particularly utilizing kitchen waste and by-products, it is essential to direct future efforts toward the commercialization of the pig industry. This should include a focus on improvements of farm structures, animal breeding, and feeding practices to improve not only pig performance but also to break routes of infectious diseases, particularly the zoonotic parasitic diseases taeniasis and cysticercosis. This will help to integrate a traditionally not well accepted or not recognized pig sector into the national livestock farming system with a massive potential for future meat production in the country. Recently, there has been an increasing number of piggery operations with a larger number of animals and a more commercialized approach. Piggery has been one of the popular agricultural business choices among youth who have returned from overseas.

4.2.4. Poultry

The poultry sector is one of the fastest-growing and probably the most commercialized livestock sub-sector in Nepal, and this sector alone contributes to the national GDP by around 3.5% [32]. Poultry production in Nepal consists of commercial broiler and layer farms, as well as village or backyard poultry production, where birds are raised in a small number in the scavenging or backyard system, while exploiting all sorts of inputs from the farmhouse itself [32]. Poultry farming in Nepal involves both commercial and native stocks, and their production shows an increasing trend [33]. A significant portion of the total poultry population consists of native breeds. Some of the documented indigenous chicken breeds of Nepal are Sakini (normal feather), Ghatikhuile (naked neck), and Pwakhulte (frizzled feather) [33]. Although the poultry sub-sector includes chickens, ducks, pigeons, and other kinds of birds kept under various production systems, the chicken population dominates by far [32]. The national population of fowl has gradually increased (~68 million in 2015 compared with ~21 million in 2001) along with a significant increase in the total chicken meat production (~55,000 tons in 2015 compared with ~14,000 tons in 2001) [20]. Chicken meat constitutes roughly 17% of total meat production, representing more than 99% of the total poultry meat production [20].

Regarding egg production, with increasing farm sizes, a higher mass of egg production and lower feed conversion rate have been observed, indicating a higher profit margin [34]. Sakini is a major native breed contributing to egg production in different regions of Nepal [35]. Support for a continued rise in commercial poultry production, improvement of the health of poultry species, and establishment of efficient marketing channels are some of the key issues the Nepalese government should prioritize in the future [36].

4.3. Wool Production in Nepal

In Nepal, no formal marketing channels exist for wool, unlike other livestock products, and farmers in different agro-ecological zones produce and utilize locally produced wool at a low scale. Although wool is recognized as a potentially valuable animal product, it has not been a major focus in the Nepalese livestock or agricultural policies, and Nepali pashmina or carpet industries rely on Tibetan wool producers due to insufficient local wool production or low wool quality [37]. Nepalese native sheep breeds have low wool productivity [38]. The production trends for wool in Nepal have, in fact, been stagnant during the past decades (60,9102 vs. 59,4312 kg in 2002 and 2017, respectively; Figure S1B) [15]. Thus, the Nepalese carpet industries rely on imported raw wool for wool-based products. Sheep are important livestock species for both meat and wool, particularly in the mountainous regions. Thus, focusing on improvements in wool, in addition to meat production from sheep, would be a sound priority when formulating regional livestock policies [39], to improve living conditions and avoid depopulation of the mountainous regions in Nepal. To

overcome the challenge of low wool production and quality in the sheep industry, strategic efforts should target a range of management practices, including breeding, harvesting, pre-processing of wool, and animal nutrition for general improvements in sheep (re-) productive performance.

5. Future Perspectives

In the following, the future perspectives for the Nepalese livestock sector will be discussed, and the role and importance of the livestock sector to ensure future food security in the country, and economic development, will be highlighted. Suggestions will be put forward for critical areas to include in Nepalese livestock development strategies to improve and sustain livestock production (Figure 4).

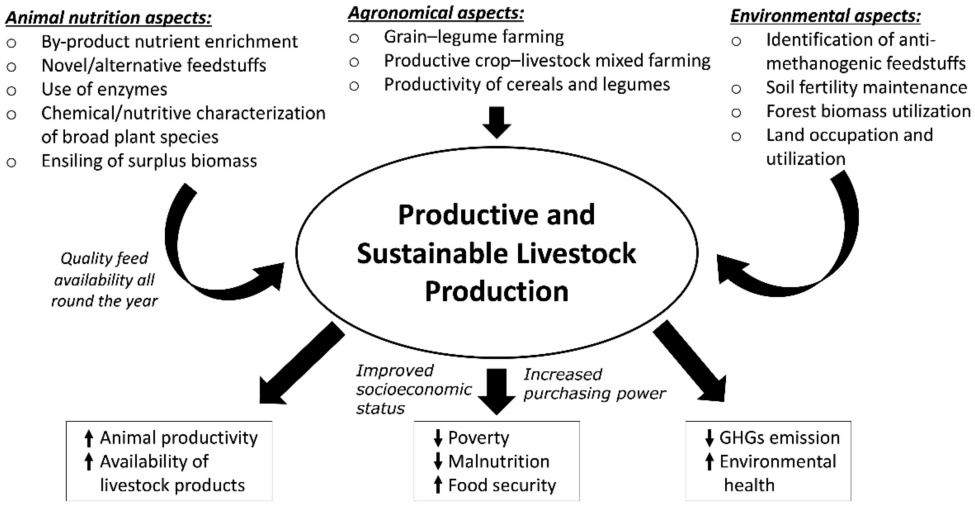

Figure 4. Future considerations to establish a productive and sustainable livestock production system in Nepal. Issues associated with animal nutrition, agronomy, and the environment are important to develop a productive livestock sector in Nepal, which could fulfill increasing demands for livestock production in changing demographic and socio-economic situations. (arrow; ↑: improvement, arrow; ↓: reduction); GHGs, greenhouse gases.

5.1. Productive and Sustainable Livestock Systems to Alleviate Poverty

Increasing population growth is a worldwide concern today. The most recent national population census of Nepal (2011) estimated the population to be 26.5 million, with a projection of a population increase to 30.4 and 33.6 million by 2021 and 2031, respectively [40]. Besides, Nepal is currently one of the least developed countries, where a significant proportion of the population lives below the poverty line (21.6%) [24]. Moreover, there is generally a poor nutritional status among people. Thus, 42%, 31%, and 14% of children were characterized as stunted, underweight, or suffering from wasting according to a Nepal Living Standards Survey (NLSS) in 2010/2011 [41]. In this respect, livestock could be a necessary tool to improve food and nutrition security and alleviate poverty, since (a) the majority of the poorer part of the rural population in the developing world (including Nepal) keep some kind of livestock, which represents a source of both income and valuable food protein [42], and (b) in a mountainous country like Nepal, conditions in vast areas for commercial crop production are poor, whereas livestock can be managed and valuable livestock-derived products can be produced in the higher hilly regions and mountains.

Previous reports have indicated that the poverty trend in Nepal is declining, particularly associated with the dynamics of both domestic migration (from rural to urban areas) and international migration (work-related migration abroad) [43], where foreign remittances have been particularly associated with poverty reduction [44]. Such migration had the following consequences for livestock production in the country: (a) the utilization of fertile land for the production of food and animal feed has declined, (b) availability of

local labor for livestock production has diminished, and (c) with increased income and better socio-economic status, per capita meat consumption and demands for livestock-derived products are growing, expanding the gap between demand and domestic supply, consequently leading to increased demand for imported meat and milk products.

As pointed out previously, the Nepalese livestock system is generally characterized by low productivity. In the following sections, the specific strategies required to develop more productive livestock systems will be discussed, since it is a priority in Nepal to become more self-sufficient in terms of feeding a growing population to alleviate (rural) poverty and improve the overall nutritional status of the population.

5.2. Alternative Livestock Feeding Strategies

In Nepal, both ruminants and monogastrics should be considered important production animals in the future. Since ruminant and non-ruminant animals have different digestive functions, nutritional requirements, and abilities to utilize various feed resources, species-specific feeding strategies need to be formulated.

Species-Specific Feeding Strategies

Ruminants: Buffalo, cattle, sheep, and goats are the major ruminant animals raised for meat or milk production in Nepal. One of the major challenges for improvement of productivity in the Nepalese ruminant livestock sector is to provide quality feed to the animals all year round, which is an important issue, since feed costs can amount to ~60% of total production costs in a typical livestock production system [45]. Due to land occupation and degradation, land availability for grazing is diminishing so the livestock sector relies more heavily on crop residues, by-products, and (novel) fodder and forage plants. For example, hempseed meal, a by-product of hemp oil production, was shown to be an alternative feeding resource for small ruminants [46]. Thus, strategies to supply sufficient amounts of nutritious feeding material all year-round should be a major strategic focus for the development of ruminant production in Nepal.

Crop–animal interaction is an integral component of mixed farming systems in Asia, including Nepal, where both crop and livestock complement resources to establish and sustain such farming systems [9]. A typical rice–wheat–maize cropping system in Nepal generates a substantial amount of straw and other by-products, which can be utilized for livestock feed. However, the nutritional quality of straw is low and methods to enrich such by-product nutrient content and use it efficiently have not been commonly practiced. It has been shown that urea treatment (up to 4% on a weight basis) enhances the voluntary intake of by-products like straw, and urea treatment can increase milk production in lactating buffalo [47]; this is due to an improved ability of microorganisms in the rumen to utilize fiber and synthesize protein for the animal, when the non-protein–nitrogen source, urea, is added to the diet. However, urea is not readily available to farmers. Alternatively, such by-products can also be pre-treated with sugar molasses [48] to increase feed intake and animal productivity. The nutritionally deficient crop by-products, such as rice straw (with high lignin and silica contents) could be enriched with the addition of alternative nutrient sources to stimulate microbial fermentation in the forestomach, such as urea, sugar molasses, ligninolytic enzymes, or microbial treatments [49].

In Nepal, precipitation during the rainy monsoon season (June–August) allows different grasses, pasture, and other fodder plants to grow, which represent substantial natural plant biomass of good nutritional quality and which can be used to feed ruminant livestock. However, in other seasons of the year (such as in winter or spring conditions), natural biomass availability is low, and particularly larger ruminants hardly get anything to eat other than the dried crop by-products of low nutritional quality. This seasonal deficit of feed materials is probably the major constraint for the improvement of ruminant production [30] and must be overcome to improve the productivity of ruminant livestock production systems. Preservation/conservation of plant biomass during the season, when it is available, is an important strategy to ensure more consistent availability of feed for

ruminants throughout their production cycle. The substantial amount of biomass available during the rainy season could be stored as hay or silage, thus preserving the available nutrients for use during the dry season, with a positive impact on overall annual animal productivity. It is noteworthy that it is not feasible to operate ensiling on a larger scale in all regions of Nepal due to topographical constraints, space limitations, and the lack of proper technologies to harvest and chop the harvested plant biomass. However, the application of low-scale ensiling techniques, such as using synthetic plastic bags or pits, could be an economical option also for small-scale farmers [50]. However, the implementation of such technologies is presently hindered by ineffective extension services and hence knowledge transfer.

In Nepal, more than 170 different species of trees, shrubs, and vine are used to provide fodder for ruminants [51]. However, there is limited information on their nutritional contents and potential biomass yields; nevertheless, three different commonly used fodder species had a large annual biomass yield of ~26–39 kg dry matter (DM)/tree [52]. Chemical analyses of ~30 different types of fodder-tree leaves revealed a relatively high crude protein content of ~10–22%, but also high contents of neutral detergent fiber (~27–74%) and acid detergent lignin (~6–30%) on a DM basis; these have strong negative impacts on DM digestibility [53]. In the hilly regions, the fodder species available for ruminant feeding as green feed will only support moderate levels of growth and milk production [54] due to the high content of indigestible components, such as lignin, which also limit the availability of protein and other nutrients for the animal [53]. Detailed chemical and nutritional characterization of various forage and fodder species potentially available as ruminant feeds are yet to be performed, and this knowledge is needed for estimations of possible improvements in productivity in the ruminant livestock sector.

Non-ruminants: Poultry and pigs are the major land-based non-ruminant species being raised in Nepal. The poultry sector is, as mentioned before, the most commercialized animal production sector, although people, particularly in rural areas, still keep a small number of local poultry breeds as a source of quality food protein, as well as for additional income from sales of eggs and meat [55]. Like in many other countries, poultry feed can contain up to 65% of corn [56]; corn is a significant energy source used for poultry production in Nepal. Corn is also one of the staple foods for human consumption in Nepal, and corn productivity is low despite some efforts in the past to try to increase productivity [57]. Due to the competition for corn for human food versus animal feed, the total annual demand for corn is growing, and thus ~45% of total corn used for animal feed is imported from India [57]. There have been some research efforts made by the National Maize Research Program, under the Nepal Agricultural Research Council, Government of Nepal, to increase the productivity of corn by developing more stress-tolerant corn varieties [58]. However, they are yet to be tested and commercialized under farm conditions in different agro-ecological zones. Pig production is still at an infant stage, although recent trends show that pork consumption is rising, particularly in urban areas, and this will call for even more efforts to improve the production of suitable feeds for monogastric animals, without competing for arable land needed for the production of food for human consumption.

In Nepal, various grain legumes are available in the winter (such as lentil, chickpea, etc.) and summer (such as soybean, black gram, etc.) seasons and they are important components of the cropping systems but are mostly used for human consumption, and their productivity is remarkably low (<1 ton/ha) [59]. Hence, overall availability of soybean for animal feeding in Asian regions is generally low [60], but soybean is, nevertheless, the major and probably most expensive feed resource used in Nepal for poultry and swine to fulfill their protein requirements. Grain legumes, including soybean, are mostly cultivated under an intercropping system, but they also have the potential to be grown as sole crops, particularly in the lower plain areas of the Terai region. Diseases and pests, soil moisture deficits in winter crops, and the unavailability of high-yielding varieties appear to be the major constraints for the upscaling of grain legume production [61]. To increase the productivity of Nepalese poultry and swine production systems, it is, therefore,

imperative to find alternative sources of feed protein to partially replace the expensive soybean meal as a protein source. Such alternative feed items could be of both animal or plant origin. One alternative protein source for non-ruminant animals, which presently is attracting interest in more developed regions of the world, is insects. Nepal hosts a diverse range of insect species [62,63], and they could become alternative sources of protein in diets for non-ruminants in the future [64]. This requires that insects depending on their growth substrate can be safely added to livestock diets without compromising the quality, safety, or palatability of meat and milk [65]. Insects can be grown on different cheap organic substrates, such as household wastes. This is an important feature in relation to the development of a more circular bioeconomy, where unutilized waste is converted into valuable protein food sources and the pollution load is reduced.

Other alternative sources of protein could be plant-based feed materials. Sunflower or mustard meals also contain high levels of protein. In one study, sunflower meal (with the addition of microzyme) could substitute up to 35% of soybean meal in the feed without compromising the growth performance of broilers [66]. Additionally, the water plant Azolla, like terrestrial legumes, can fix atmospheric nitrogen and convert it into protein. Azolla has been identified as a possible economical substitute for soybean-based poultry feed and can replace up to 10% of soybean meal in the overall diet [67].

The availability of quality feeds all year round is important to sustain animal production and exploit the genetic potential of livestock. Specific research and extension services should be prioritized in Nepal to effectively utilize current feed resources and formulate implementable, alternative, and efficient new feeding strategies. Particular attention should be paid to enrich the nutritional values of various plant-based by-products. Also, cost-effective small-scale technologies should be developed to preserve the chemical and nutritional properties of seasonally available surplus plant biomass. Additionally, a detailed evaluation of biomass yields, chemical and nutritional properties, and digestibility of a broader range of available forage and fodder species is vital to optimize future feed formulations. Future strategies should also be directed towards identifying alternative nutritious feed resources, such as insects, and assessing them for palatability, utilization, and impacts on animal health, growth, and performance. While formulating future livestock strategies, it is noteworthy that ruminants have advantages over non-ruminants, since they are not necessarily in direct competition with humans for food resources, which is critical for a developing country like Nepal, but feed resources for ruminant animals should nevertheless have a reasonably high digestibility to achieve significant improvements in animal production.

5.3. Feeding Strategies for Reduced Climate Impact

The livestock sector's contribution to climate change has become a global issue, as the livestock sector alone accounts for about one-fifth of total GHG emissions [68]. In Nepal, it has been estimated that agriculture and forestry, and other land-use sectors account for >80% of national GHG emissions [69]. Enteric emissions from ruminant livestock and emissions from agricultural soils are the major contributors [70]. The climate mitigation policies directed at GHG emission from the livestock sector and particularly enteric methane emission from ruminant livestock should be implemented with extreme caution. Assessing the negative impact of livestock-derived GHGs should be balanced against the positive benefits relating to food security and poverty alleviation since livestock is a vital source of nutrition and livelihood for many low-income people in countries like Nepal [71,72]. The global average meat consumption is ~100 g per person per day with an about ten-fold variation between the highest and lowest consuming parts of the population [68]. In Nepal, with a transition in socio-economic status and income rise, per capita meat consumption will increase, which is expected to lead to beneficial trade-offs in terms of improvements in nutritional status. However, this also calls for a transition of livestock production systems from the traditional extensive production system to more intensified and resource-efficient systems to ensure increments in productivity are achieved without associated increments

in GHG emissions. Improving livestock production efficiency through better breeding techniques and feed utilization strategies is essential in this respect since the most important determinant for methane emission per kg produce is animal productivity [73].

Other possibilities to reduce emissions from the ruminant livestock sector could be to exploit feed additives with anti-methanogenic properties in diets for ruminants. This is becoming a topic of interest in the European Union, where climate policies dictate a 40% reduction in GHG emissions by the year 2030 compared with 2014, which is likely to be backed by political instruments, such as taxation on livestock production [74]. Various types of plants have been shown to contain bioactive, anti-methanogenic compounds, but to the best of our knowledge, no research has been conducted in this field on indigenous plants from Nepal.

To sum up, long-term strategies to minimize GHG emissions from the livestock sector in a developing country like Nepal should involve (1) the transition of particularly the existing ruminant livestock sector towards more productive systems, and (2) identification of potential anti-methanogenic plants/compounds suitable to use as feed additives for ruminant livestock.

The livestock sector is not only a culprit, but also itself becoming a victim, of climate change; it is vulnerable to the adverse impacts of climate change on the environment and feed availability for livestock in the developing world [75]. In Nepal, the livestock sector is, as already mentioned, an integral component of mixed farming systems. The increased frequency of drought, extreme rain, hailstorms, floods, erratic rainfall patterns, etc., are some of the observed effects of climate change with negative impacts on the existing farming system [76,77]. Thermal stress has direct adverse effects on animal health, reproductive, and productive performances of livestock, whereas adverse abiotic conditions, such as droughts and heat stress, lead to undesirable impacts on forage and crop production, thus limiting plant biomass supply for feeding of production animals [78,79]. Although there are some early indications of adverse climate change impacts, it is yet too soon to fully understand the extent of climate change impacts on the livestock sector in different regions of Nepal with its diverse agro-climatic conditions and agro-livestock systems. Climate impacts on livestock production may, therefore, be very different in different areas [80]. In Nepal, limited research has been conducted concerning livestock adaptation to climate change, and most research efforts have taken only ruminant species into account. Thus, future studies are needed to acquire a better understanding of the impacts of climate change on different livestock production systems, taking both ruminants and non-ruminants into account, and considering key issues, such as forage and pasture availability, animal performance characteristics (meat, milk, and egg production and feed conversion efficiency). Such information is essential to perform a holistic economic analysis of livestock systems under climate change and develop the most appropriate region-specific future strategies for adaptation and reduction of GHG emissions.

6. Future Livestock Policies

In Nepal, the Ministry of Agriculture and Livestock Development (MOALD) (http://moald.gov.np/, accessed on 8 December 2021) is responsible for the formulation, implementation, monitoring, and evaluation of livestock-related policies, plans, and programs, and the Department of Livestock Services (DLS) is mainly liable for livestock-related extension activities. Moreover, the Nepal Agricultural Research Council (NARC) (www.narc.gov.np, accessed on 8 December 2021) carries out major agricultural research activities at the National Animal Science Research Institute (NASRI), with various disciplinary divisions targeting different livestock sectors. Agricultural universities, mainly the public Agriculture and Forestry University (AFU) and Tribhuvan University (TU), and some private institutions carry out teaching activities to fulfill academic requirements for various study programs in animal and veterinary sciences. In Nepal, collaboration within and across governmental livestock bodies and industry sectors could generate needed

synergies to improve livestock productivity. Unfortunately, such coordinated efforts have been missing so far.

Detailed analysis of the national agricultural policies of Nepal have been reported elsewhere, suggesting a need for a separate livestock policy rather than the previously formulated common agricultural policies (see review by [37]) and agriculture perspective plans (1995/96–2014/2015) [81]. In this paper, we propose that a future separate livestock policy should be formulated, which (a) acknowledges animal feed as a pivotal component to improve livestock productivity, (b) prioritizes the capacity building of research institutions to uplift livestock research, and (c) recognizes the industry sector as a key player in Research–Academia–Industry (RAI) partnerships to promote future research and sector development activities (Figure 5).

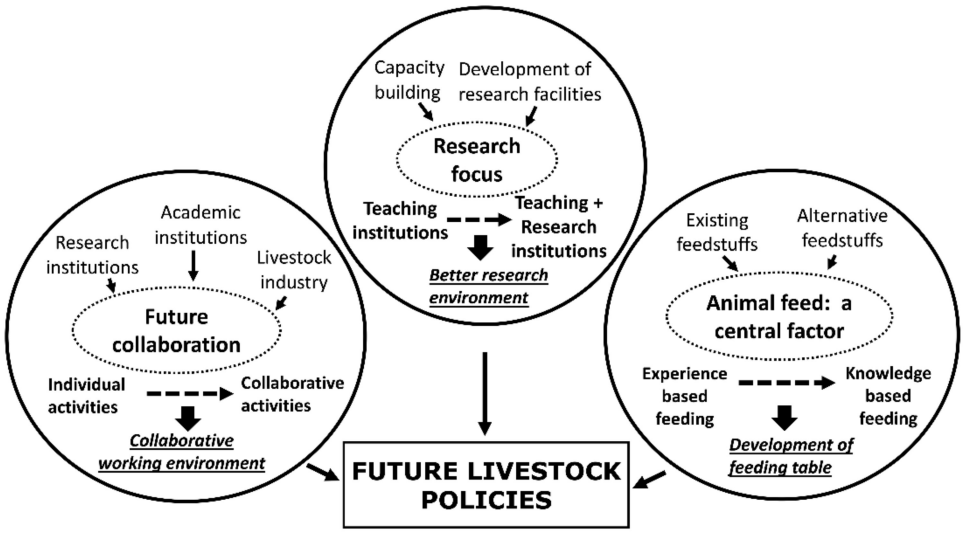

Figure 5. Formulation of future livestock policies in Nepal. Future livestock policies should focus on creating a better research environment and collaborative networks among research, academic, and industry sectors where animal nutrition should be recognized as a central player to improve existing production systems and exploit the genetic potentials of future livestock production systems.

6.1. Animal Feed—A Pivotal Component of the Future Livestock Policies

Poor animal productivity is recognized as a major issue in Nepal, like in many other developing countries [82]. We highlight that providing quality feed for livestock is probably the first and most important factor in improving animal productivity in Nepal as this strategy is also helpful in reducing methane production by increasing the production per unit of animal [83]. This is particularly important because feed costs account for ~60% of total livestock production costs [45], and the provision of quality feeds is necessary to fully exploit the genetic potential of production animals. Thus, any breeding program, particularly for ruminants, would not succeed without ensuring the availability of quality feed year-round. In this context, Nepal's future national livestock policies should identify production, supply and optimized use of quality animal feeds as the central focal point.

Compiling information about feed quality in the form of feeding tables is a critical step in ensuring that proper feeding plans can be formulated to fulfill the nutritional requirements of specific animals. Such tables should integrate nutrition characteristics of (a) existing commonly used feedstuffs and the impact of post-harvest processing, (b) identify alternative feedstuffs, and (c) encompass seasonal and regional/geographical variations and other potential factors that could influence the nutritional values of the feedstuffs. Presently, planning of animal feeding in Nepal is rarely based on scientific knowledge about the feed, but rather on the livestock farmers' experiences, which may not always ensure the most resource-efficient outcomes.

To improve the preservation, quality, and utilization of existing feedstuffs for ruminant species, preservation, and storage of seasonally available forage and fodder biomass should be a top priority. Farmers must have easier access to nutrient enrichment technologies to improve the nutritional values of crop residues and by-products. The use of marginal or underutilized lands, where virtually no crop production is possible, for growing grasses, forages, and fodder trees should be prioritized, and potentials for the utilization of forest biomass and new plant species under agroforestry models should be evaluated.

As an immediate action, the livestock sector should collaborate with crop development companies and research divisions to increase maize productivity and expand legume cultivation to ensure a greater future reliance on home-grown energy and protein resources. Expanded productivity of these crops is imperative to prevent increased competition from livestock for these crops that are primarily utilized as foods for humans. The utilization of natural pastures and meadows in hilly areas can also improve the export potential of organic livestock products in the future. The long-term policy strategy should focus on the potential for producing novel protein sources that can be less competitive with humans for food, and insects and Azolla are fascinating in this regard. Proper capacity and infrastructure building of research institutions are crucial to identify and evaluate the suitability of existing and novel feed resources, as discussed in the following sections.

6.2. Capacity and Infrastructure Building of Research Institutions

Like in many other developing countries, an insufficient research capacity, not least in the livestock field, is a significant concern in Nepal. Future livestock policies should be directed towards developing better research environments to address upcoming vital issues associated with livestock production and management, particularly efficient utilization of existing and alternative feedstuffs and the development of new feed resources. Traditionally, the NARC has been the only institution devoted to livestock research. Its available laboratory facilities and human resources should be upgraded to perform, for example, large-scale in vitro analyses to characterize feed digestibility, which is the major determinant of energy and protein value of feeds. Besides, animal experimental facilities should be equipped to enable in vivo studies that characterize the impacts of existing and novel feeding resources on animal performance. Facilities to assess potential anti-methanogenic properties of existing or novel feedstuffs are also highly relevant in this context, so as to be able to design the most productive, as well as climate-friendly, strategies for livestock sector development.

Historically, Nepalese academic institutions are dedicated to fulfilling only the academic requirements of various study programs, including animal and veterinary sciences. Future livestock education policies should aim to transform the existing universities into more research-based institutions, thus prioritizing both research and teaching as their major activities. This will help to uplift the research capability and contribute to establishing research-based university education training and teaching programs. This will also strengthen positive collaborations between universities and research institutions to develop joint project proposals and establish a research-based, potentially international, learning environment in animal science.

6.3. Research–Academia–Industry (RAI) Collaborations

In Nepal, research and academia are separate pillars, and neither appear to have strong traditions for research collaboration with the industry sector. Livestock industries are currently in a growing phase, and many feed industries of different sizes are already in existence, mainly focusing on poultry feed formulations. Research efforts in Nepal are poorly connected with business sectors, which makes it difficult to commercialize research outputs to promote industrial growth in the livestock sector. Industry sectors can provide important tools for livestock research, such as animals and animal facilities, as well as resources to carry out different research activities. Both research and the academic level in Nepal could benefit from such collaborations with the industry sector, as international

experiences have shown in other parts of the world. Thus, integrated future livestock policies should include instruments (e.g., National research funding) to promote research–academia–industry (RAI) collaborations to develop a sustainable livestock industry sector.

7. Conclusions

The livestock sector is an integral component of Nepalese mixed farming systems, providing high-quality food, income, and livelihood to millions of people residing in a poor socio-economic setting. The livestock sector is currently facing the principal challenge of low productivity and cannot fulfill the national demands for livestock products. This situation will be exacerbated in the future in light of population growth and increased per capita meat and milk consumption associated with improved socio-economic status. Thus, to ensure that the livestock sector will be able to feed future generations, specific livestock-associated future policies must be developed to promote the sustainable development of the livestock sector and livestock management systems. In future livestock policies, the availability of quality feed for livestock should be acknowledged as one of the primary elements to exploit the existing or to-be-improved genetic potentials of production animals, and efforts should be directed towards developing an easy-to-use feeding table for farmers by evaluating nutrient and digestibility characteristics of existing, as well as potential future, feed resources. Additionally, capacity building and infrastructure development at public universities and research institutions relating to animal nutrition, feeding, health, and performance are important to formulate needed region-specific strategies to ensure the development of a productive, as well as climate-friendly, livestock sector, adapted to the prevailing agro-ecological conditions in the future. Industry sectors should be identified and acknowledged as important players in this respect. Future livestock policies should include instruments that will encourage RAI partnerships within research collaboration and promote the implementation of future strategic measures targeting the Nepalese livestock sector.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture12050679/s1, Figure S1: Status of sheep meat and wool production.

Author Contributions: Conceptualization, P.K.; methodology, P.K., R.D., D.P. and M.O.N.; writing—original draft preparation, P.K., R.D., T.K. and D.P.; writing—review and editing, P.K., R.D., T.K., D.P., N.R.D. and M.O.N.; visualization, P.K. and D.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data used in this paper can be accessed by using the links provided in the paper.

Acknowledgments: The authors would like to thank Bishnu Adhikari (Children's Mercy Hospital, Kansas City, USA), Nabin Aryal (University of Southeastern Norway, Norway), Balram Bhandari (Nepal Agricultural Research Council, Nepal), and Yadav Sharma Bajagai (Central Queensland University, Australia) for their fruitful discussions and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Steinfeld, H.; Gerber, P.; Wassenaar, T.; Castel, V.; De Haan, C. *Livestock's Long Shadow: Environmental Issues and Options*; FAO: Rome, Italy, 2006.
2. FAO. *The Future of Food and Agriculture—Alternative Pathways to 2050*; FAO: Rome, Italy, 2018; p. 224.
3. Herrero, M.; Thornton, P.K.; Gerber, P.; Reid, R.S. Livestock, livelihoods and the environment: Understanding the trade-offs. *Curr. Opin. Environ. Sustain.* **2009**, *1*, 111–120. [CrossRef]

4. Alexandratos, N.; Bruinsma, J. *World Agriculture towards 2030/2050: The 2012 Revision*; ESA Working paper; FAO: Rome, Italy, 2012.
5. Mizrahi, I.; Wallace, R.J.; Moraïs, S. The rumen microbiome: Balancing food security and environmental impacts. *Nat. Rev. Microbiol.* **2021**, *19*, 553–566. [CrossRef] [PubMed]
6. Höglund-Isaksson, L. Global anthropogenic methane emissions 2005–2030: Technical mitigation potentials and costs. *Atmos. Chem. Phys.* **2012**, *12*, 9079–9096. [CrossRef]
7. Henderson, B.; Golub, A.; Pambudi, D.; Hertel, T.; Godde, C.; Herrero, M.; Cacho, O.; Gerber, P. The power and pain of market-based carbon policies: A global application to greenhouse gases from ruminant livestock production. *Mitig. Adapt. Strateg. Glob. Change* **2018**, *23*, 349–369. [CrossRef]
8. Mehrabi, Z.; Gill, M.; Wijk, M.v.; Herrero, M.; Ramankutty, N. Livestock policy for sustainable development. *Nat. Food* **2020**, *1*, 160–165. [CrossRef]
9. Devendra, C.; Thomas, D. Crop–animal systems in Asia: Importance of livestock and characterisation of agro-ecological zones. *Agric. Syst.* **2002**, *71*, 5–15. [CrossRef]
10. Herrero, M.; Grace, D.; Njuki, J.; Johnson, N.; Enahoro, D.; Silvestri, S.; Rufino, M.C. The roles of livestock in developing countries. *Animal* **2013**, *7* (Suppl. S1), 3–18. [CrossRef]
11. Population Reference Bureau. 2012 World Population Data Sheet. Available online: https://www.prb.org/wp-content/uploads/2012/07/2012-population-data-sheet_eng.pdf (accessed on 12 November 2021).
12. Thornton, P. *Mapping Poverty and Livestock in the Developing World*; ILRI (aka ILCA and ILRAD): Nairobi, Kenya, 2002; Volume 1.
13. Mottet, A.; Tempio, G. Global poultry production: Current state and future outlook and challenges. *World's Poult. Sci. J.* **2017**, *73*, 245–256. [CrossRef]
14. Enahoro, D.; Mason-D'Croz, D.; Mul, M.; Rich, K.M.; Robinson, T.P.; Thornton, P.; Staal, S.S. Supporting sustainable expansion of livestock production in South Asia and Sub-Saharan Africa: Scenario analysis of investment options. *Glob. Food Secur.* **2019**, *20*, 114–121. [CrossRef]
15. MOALD. *Statistical Information on Nepalese Agriculture (2016/2017)*; Ministry of Agriculture and Livestock Development: Kathmandu, Nepal, 2017.
16. MOALD. *Statistical Information on Nepalese Agriculture (2018/2019)*; Ministry of Agriculture and Livestock Development: Kathmandu, Nepal, 2019.
17. Muehlhoff, E.; Bennett, A.; McMahon, D. *Milk and Dairy Products in Human Nutrition*; FAO: Rome, Italy, 2013.
18. CBS. *National Population and Housing Census 2011 (Population Projection 2011–2031)*; CBS: Kathmandu, Nepal, 2014; pp. 1–78.
19. Sanwal, B.D. Nepal—An Introduction. Available online: https://aspace.repository.cam.ac.uk/bitstream/handle/1810/242729/bot_03_02_04.pdf?sequence=1&isAllowed=y (accessed on 8 December 2021).
20. MOALD. *Statistical Information on Nepalese Agriculture*; Ministry of Agriculture and Livestock Development: Kathmandu, Nepal, 2016.
21. ADS. *Agriculture Development Strategy (ADS) 2015–2035*; Government of Nepal, Ministry of Agricultural Development: Kathmandu, Nepal, 2015.
22. Wilson, R.T. Animal genetic resources and domestic animal diversity in Nepal. *Biodivers. Conserv.* **1997**, *6*, 233–251. [CrossRef]
23. CBS. *Central Bureau of Statistics—A Compendium of National Statistical System of Nepal*; National Planning Commission Secretariat: Kathmandu, Nepal, 2017.
24. MOF. *Econmic Survery*; Government of Nepal, Ministry of Finance: Kathmandu, Nepal, 2017.
25. Moioli, B.; Borghese, A. *Buffalo Breeds and Management Systems. Buffalo Production and Research*; FAO: Rome, Italy, 2005; pp. 51–76.
26. Devendra, C. Small ruminants in Asia; Contribution to food security, poverty alleviation and opportunities for productivity enhancement. In Proceedings of the International Workshop on Small Ruminant Production and Development, South East Asia, Ho Chi Minh City, Vietnam, 2–4 March 2005; pp. 19–32.
27. Rajwar, N.B. *National Goat Development Strategies and Outcomes*; National Agriculture Research Council (NARC): Kathmandu, Nepal, 2013.
28. Shrestha, B.S.; Pokharel, P.K. *Potential and Performances of Goat Breeds and Future Breeding Strategies for Commercialization of Goat Production in Nepal*; National Agriculture Research Council (NARC): Kathmandu, Nepal, 2012.
29. Oli, K.P.; Gatenby, R.M. Goat and sheep production in the hills and mountains of Eastern Nepal. *Int. J. Anim. Sci.* **1990**, *5*, 41–47.
30. Rauniyar, G.; Upreti, C.; Gavigan, R.; Parker, W. Constraints to Sheep Farming in Nepal: Development Challenge for Poverty Alleviation. *Asian-Australas. J. Anim. Sci.* **2000**, *13*, 1162–1172. [CrossRef]
31. Nidup, K.; Joshi, D.D.; Gongora, J.; Moran, C. Farming and biodiversity of indigenous pigs in Nepal. *Biodiversity* **2010**, *11*, 26–33. [CrossRef]
32. FAO. *Poultry Sector Nepal*; FAO Animal Production and Health Livestock Country Reviews; No. 8.; FAO: Rome, Italy, 2014.
33. Gorkhali, N.A.; Sherpa, C.; Kolachhapati, M.R.; Pokharel, B.R.; Bhattarai, N.; Sapkota, S. Intermixing of Commercial Pure Breed Chickens with Indigenous (Sakini) Breed of Nepal. *J. Nepal Agric. Res. Counc.* **2021**, *7*, 92–96. [CrossRef]
34. Osti, R.; Zhou, D.; Singh, V.; Bhattarai, D.; Chaudhary, H. An economic analysis of poultry egg production in Nepal. *Pak. J. Nutr.* **2016**, *15*, 715–724. [CrossRef]
35. Sapkota, S.; Kolachhapati, M.; Devkota, N.; Gorkhali, N.; Bhattarai, N. Evaluation of Egg Laying and Egg Quality Parameters of Local. *J. Agric. For. Univ.* **2017**, *1*, 181.
36. Osti, R.; Bhattarai, D.; Chaudhary, H.; Singh, V. Poultry production in Nepal: Characteristics, productivity and constraints. *Int. J. Appl. Sci. Biotechnol.* **2017**, *5*, 222–226. [CrossRef]

37. Pradhanang, U.B.; Pradhanang, S.M.; Sthapit, A.; Krakauer, N.Y.; Jha, A.; Lakhankar, T. National Livestock Policy of Nepal: Needs and Opportunities. *Agriculture* **2015**, *5*, 103–131. [CrossRef]
38. Upreti, C.; Shrestha, B. *Sheep and Wool Production Systems in Nepal*; FY 2052/53 (1995/96); Sheep and Goat Research Program, Nepal Agricultural Research Council: Jumla, Nepal, 1996.
39. Paudel, M.N. Prospects and limitations of agriculture industrialization in Nepal. *Agron. J. Nepal* **2016**, *4*, 38–63. [CrossRef]
40. CBS. *National Population and Housing Census 2011*; National Report; Government of Nepal, Central Bureau of Statistics: Kathmandu, Nepal, 2012.
41. CBS. *Nepal Living Standards Survey 2010/11 (NLSS)*; Dataset; Central Bureau of Statistics: Kathmandu, Nepal, 2011.
42. Pica-Ciamarra, U.; Tasciotti, L.; Otte, J.; Zezza, A. *Livestock Assets, Livestock Income and Rural Households: Evidence from Household Surveys*; FAO: Rome, Italy, 2011.
43. Lokshin, M.; Bontch-Osmolovski, M.; Glinskaya, E. Work-related migration and poverty reduction in Nepal. *Rev. Dev. Econ.* **2010**, *14*, 323–332. [CrossRef]
44. Wagle, U.R.; Devkota, S. The impact of foreign remittances on poverty in Nepal: A panel study of household survey data, 1996–2011. *World Dev.* **2018**, *110*, 38–50. [CrossRef]
45. Becker, G.S. *Livestock Feed Costs: Concerns and Options*; Congressional Research Service, Library of Congress: Washington, DC, USA, 2008.
46. Abrahamsen, F.W.; Gurung, N.K.; Abebe, W.; Reddy, G.P.; Mullenix, K.; Adhikari, S. Effects of feeding varying levels of hempseed meal on dry matter intake, rumen fermentation, in vitro digestibility, blood metabolites, and growth performance of growing meat goats. *Appl. Anim. Sci.* **2021**, *37*, 681–688. [CrossRef]
47. Chemjong, P.B. Economic value of urea-treated straw fed to lactating buffaloes during the dry season in Nepal. *Trop. Anim. Health Prod.* **1991**, *23*, 147–154. [CrossRef]
48. Upreti, C.; Kuwar, B.; Panday, S. Possible use of crop residues supplemented with urea and molasses in goat diets. *Nepal J. Sci. Technol.* **2006**, *7*, 59–64. [CrossRef]
49. Malik, K.; Tokkas, J.; Anand, R.C.; Kumari, N. Pretreated rice straw as an improved fodder for ruminants-An overview. *J. Appl. Nat. Sci.* **2015**, *7*, 514–520. [CrossRef]
50. Khandaker, Z.; Uddin, M. Cost-effective preservation technique of green fodder and its impact on quality of silage. *Livest. Res. Rural. Dev.* **2013**, *25*, 233–243.
51. Shrestha, R.; Tiwari, B. Nutritional value and tannin content of some common fodder tree species of the western hills of Nepal. In Proceedings of the Fourth Meeting of the Working Group on Fodder Trees, Forest fodder and leaf litter, Kathmandu, Nepal, 3–5 December 1991; FRD occasional paper. p. 92.
52. Upreti, S.; Devkota, N. Ranking of Fodder Tree Species and Their Biomass Production in the Hills and Mountain of Nepal. *J. Agric. For. Univ.* **2017**, *1*, 171.
53. Khanal, R.C.; Subba, D.B. Nutritional evaluation of leaves from some major fodder trees cultivated in the hills of Nepal. *Anim. Feed. Sci. Technol.* **2001**, *92*, 17–32. [CrossRef]
54. Khanal, R.; Upreti, C. Evaluation of selected species of tree fodders cultivated for feeding ruminants in the hills of Nepal. *Pak. J. Nutr.* **2008**, *7*, 297–302. [CrossRef]
55. Guèye, E. Family poultry research and development in low-income food-deficit countries: Approaches and prospects. *J. Outlook Agric.* **2002**, *31*, 13–21. [CrossRef]
56. Hellin, J.; Erenstein, O. Maize-poultry value chains in India: Implications for research and development. *J. New Seeds* **2009**, *10*, 245–263. [CrossRef]
57. Govind, K.; Karki, T.B.; Shrestha, J.; Achhami, B.B. Status and prospects of maize research in Nepal. *J. Maize Res. Dev.* **2015**, *1*, 1–9.
58. NMRP. *Annual Report 2073/74 (2016/17)*; National Maize Research Program (NMRP), NARC: Rampur, Nepal, 2017.
59. Gharti, D.; Darai, R.; Subedi, S.; Sarker, A.; Kumar, S. Grain legumes in Nepal: Present scenario and future prospects. *World J. Agric. Res.* **2014**, *2*, 216–222.
60. Ravindran, V.; Blair, R. Feed resources for poultry production in Asia and the Pacific. II. Plant protein sources. *World's Poult. Sci. J.* **1992**, *48*, 205–231. [CrossRef]
61. Shrestha, R.; Neupane, R.; Adhikari, N. Status and future prospects of pulses in Nepal. In Proceedings of the Regional Workshop on Pulse Production, Nepal Agricultural Research Council (NARC), Kathmandu, Nepal, 24–25 October 2011; pp. 24–25.
62. Thapa, V.K. *An Inventory of Nepal's Insects*; IUCN-The World Conservation Union: Kathmandu, Nepal, 1997.
63. Harper, P. Capniidae, Leuctridae, and Perlidae (Plecoptera) from Nepal. *J. Orient. Insects* **1977**, *11*, 53–62. [CrossRef]
64. Moreki, J.; Tiroesele, B.; Chiripasi, S. Prospects of utilizing insects as alternative sources of protein in poultry diets in Botswana: A review. *J. Anim. Sci. Adv.* **2012**, *2*, 649–658.
65. Khusro, M.; Andrew, N.; Nicholas, A. Insects as poultry feed: A scoping study for poultry production systems in Australia. *World's Poult. Sci. J.* **2012**, *68*, 435–446. [CrossRef]
66. Dhakal, H.; Sah, R.; Karki, D.N.; Yadav, J.; Tiwari, M.R. Replacement effects of soybean meal with different levels of sunflower meal with or without enzyme on performance of Cobb-500 broilers. *Nepal. J. Agric. Sci.* **2015**, *13*, 29–37.
67. Paudel, D.R.; Dhakal, P.; Timsina, K.P.; Dahal, A. Azolla as an Economic Substitute to Soybean Based Feed for Poultry. *Int. J. Appl. Sci. Biotechnol.* **2015**, *3*, 619–625. [CrossRef]

68. McMichael, A.J.; Powles, J.W.; Butler, C.D.; Uauy, R. Food, livestock production, energy, climate change, and health. *Lancet* **2007**, *370*, 1253–1263. [CrossRef]
69. MOSTE. *Nepal Second National Communication to United Nations Framework Convention on Climate Change*; Ministry of Science, Technology, and Environment, Government of Nepal: Kathmandu, Nepal, 2014.
70. Pradhan, B.B.; Shrestha, R.M.; Hoa, N.T.; Matsuoka, Y. Carbon prices and greenhouse gases abatement from agriculture, forestry and land use in Nepal. *Glob. Environ. Change* **2017**, *43*, 26–36. [CrossRef]
71. Havlík, P.; Valin, H.; Herrero, M.; Obersteiner, M.; Schmid, E.; Rufino, M.C.; Mosnier, A.; Thornton, P.K.; Böttcher, H.; Conant, R.T.; et al. Climate change mitigation through livestock system transitions. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 3709–3714. [CrossRef]
72. Gill, M.; Smith, P.; Wilkinson, J.M. Mitigating climate change: The role of domestic livestock. *Animal* **2010**, *4*, 323–333. [CrossRef]
73. Gerber, P.; Vellinga, T.; Opio, C.; Steinfeld, H. Productivity gains and greenhouse gas emissions intensity in dairy systems. *Livest. Sci.* **2011**, *139*, 100–108. [CrossRef]
74. EU Commission. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions–A European Agenda for the collaborative economy*; EU Commission: Brussel, Belgium, 2016.
75. Thornton, P.K.; van de Steeg, J.; Notenbaert, A.; Herrero, M. The impacts of climate change on livestock and livestock systems in developing countries: A review of what we know and what we need to know. *Agric. Syst.* **2009**, *101*, 113–127. [CrossRef]
76. Dahal, P.; Shrestha, N.S.; Shrestha, M.L.; Krakauer, N.Y.; Panthi, J.; Pradhanang, S.M.; Jha, A.; Lakhankar, T. Drought risk assessment in central Nepal: Temporal and spatial analysis. *Nat. Hazards* **2016**, *80*, 1913–1932. [CrossRef]
77. Hussain, A.; Rasul, G.; Mahapatra, B.; Wahid, S.; Tuladhar, S. Climate change-induced hazards and local adaptations in agriculture: A study from Koshi River Basin, Nepal. *Nat. Hazards* **2018**, *91*, 1365–1383. [CrossRef]
78. Nardone, A.; Ronchi, B.; Lacetera, N.; Ranieri, M.S.; Bernabucci, U. Effects of climate changes on animal production and sustainability of livestock systems. *Livest. Sci.* **2010**, *130*, 57–69. [CrossRef]
79. Koirala, A.; Shrestha, K. Effects of climate change on the livestock population in Mustang District, Nepal. *Asian J. Agric. Dev.* **2017**, *14*, 37–49.
80. Panthi, J.; Aryal, S.; Dahal, P.; Bhandari, P.; Krakauer, N.Y.; Pandey, V.P. Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. *Reg. Environ. Change* **2016**, *16*, 1121–1132. [CrossRef]
81. Upadhyay, N.; Timsina, K.; Gairhe, S.; Sapkota, S.; Acharya, Y.; Khadka, S. Growth of livestock sector in Nepal: A perspective on agriculture perspective plan. In Proceedings of the 10th National Workshop on Livestock and Fisheries Research in Nepal, Lumle, Nepal, 23 September 2017; p. 7.
82. Thomas, D.; Zerbini, E.; Rao, P.P.; Vaidyanathan, A. Increasing animal productivity on small mixed farms in South Asia: A systems perspective. *Agric. Syst.* **2002**, *71*, 41–57. [CrossRef]
83. Knapp, J.R.; Laur, G.; Vadas, P.A.; Weiss, W.P.; Tricarico, J.M. Invited review: Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. *J. Dairy Sci.* **2014**, *97*, 3231–3261. [CrossRef]