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Life cycle sustainability assessment of an agricultural product in rural areas of Western Nepal—case study of goat meat

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Abstract

Purpose In Nepal, goat farming plays a vital role in the agricultural economy and food security, and this number is increasing. The purpose of this study was to understand the sustainability impacts of this highly important food item and to test a life cycle assessment method for an agricultural product in Nepal for the first time.

Methods Life cycle sustainability assessment (LCSA) was applied to assess the carbon footprint, social impacts, and life cycle costs of goat meat produced in Western Nepal in Sudurpashchim and Karnali Provinces. Primary data were collected from goat farms, field cultivation, middlemen, and butcheries to assess climate impact and costs. Goat farmer group discussions were held to cover social impacts.

Results and discussion The carbon footprint of the carcass weight of the goat meat was 17 kg CO_2eq/kg CW. Further studies should focus on methane emissions from enteric fermentation and manure and the overall efficiency of the production chain. The results indicate that, in general, the goat business is a good business, but profitability is mostly toward the downstream side of the value chain, especially for butchers selling directly to customers. Meeting basic needs, access to services and inputs, and women's empowerment were identified as social hotspots in several regions.

Conclusions LCSA is an applicable method in the food and agricultural sector in Nepal and provides several possibilities for the future. By integrating environmental, social, and economic perspectives, future interventions can better support small-scale farmers, enhance their livelihoods, and promote sustainable agricultural practices.

Keywords Goat · Nepal · Life cycle sustainability assessment · Life cycle assessment · LCA · Social LCA · LCC

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1 Introduction

Goat meat, commonly known as chevon, is a valuable source of protein for rural households across Asia. Compared with beef, pork, and lamb, chevon is low in fat and cholesterol, making it a healthier, low-calorie protein option (Mazhangara et al. 2019). Globally, there are an estimated 1 billion goats, with Asia and Africa as leading producers. Asia alone contributes approximately 4 million tons of fresh and grilled goat meat, accounting for nearly 50% of global production (FAOSTAT, 2022). In Nepal, goat farming plays a vital role in the agricultural economy and food security, with a reported 13 million goats and 74,241 metric tons (Mt) of meat produced in 2021/22 (MoALD 2023), meeting an estimated 86% of the country's demand (Sapkota et al. 2021), whereas goat farming contributes nearly 3.2% of the agricultural gross domestic product (AGDP) and 14.47% of Nepal's total meat production (MoALD 2023).

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The population of goats has increased from 9,512,958 to 13,990,703 in the past 10 years (MoALD 2023). Consequently, goat farming has become an important source of livelihood for smallholder farmers in rural and semi-urban areas, providing food, income, and economic resilience.

Although goats are domesticated primarily for their meat, they also provide milk, hide, manure, and labor, particularly in mountainous and hilly regions where they are used to carry light loads. The goat breeds commonly raised in Nepal include indigenous varieties such as Terai, Khari, Sinhal, and Chyangra, along with foreign breeds such as Boer, Barbari, Saanen, Beetal, Sirohi, Jamunapari, and their hybrids (Rana et al. 2022). Goats are well suited to Nepal's diverse and often harsh climates, requiring minimal investment, as they primarily graze on readily available forage from community forests and grasslands. The main feeding practices for goats in Nepal include 31.48% grazing, 53.16% grass/hay, and 13.16% domestic feed, with only a few purchased feeds (NSO 2023). Recognizing their role in food security and rural livelihoods, the Nepalese government prioritized goat farming in its agricultural development strategy (2015–2035) and introduced programs and subsidies to support goat production. Currently, approximately 62% of the goats produced in the country are produced by smallholder farmers with 0.2–1 ha of land (NSO 2023).

As small ruminants, goats integrate easily into Nepal's farming system and serve as a complementary enterprise for rural households, particularly in regions such as the mid-hill and Terai regions, where youth outmigration has impacted labor availability (Maharjan et al. 2013). Women, elderly individuals, and children typically manage goat farming in these areas, making it an accessible and low-cost livestock business for resource-constrained farmers (Neupane et al. 2018; Panth et al. 2021). Farmers often rely on natural fodder from agroforestry systems, agricultural fields, and nearby communities to sustain their herds. However, despite its potential, goat farming productivity is hindered by several challenges, including limited technical knowledge and resources, inadequate awareness of proper shed construction, insufficient vaccination practices for diseases such as Peste de Petits ruminants (PPR), unfamiliarity with livestock insurance options, and limited knowledge of improved breeding practices (Jaisi et al. 2016).

In addition to these production challenges, goats contribute to greenhouse gas (GHG) emissions, a growing concern in the agricultural sector. Livestock emissions vary significantly on the basis of factors such as region, season, animal size and age, feeding methods, feed composition, and manure management practices (Wei et al. 2023; Masse et al., 2016; Ricci et al. 2013; IPCC 2019a). Enteric CH_4 emissions and manure CH_4 and N_2O are the primary sources of GHG emissions from the agricultural sector, with manure contributing approximately 10% (47 Gg) and the remainder from enteric fermentation (MoSTE 2014). While meat consumption in Nepal remains relatively low, ruminants, including goats, are significant contributors to GHG emissions. Measuring these emissions is crucial for identifying mitigation potential and guiding sustainable agricultural practices, as well as supporting the current initiatives of the Government of Nepal towards sustainable food systems. As part of the UN Food Systems Summit 2021, the National Planning Commission (NPC) of Nepal conducted a series of dialogues on food system transformation and highlighted boosting nature-positive production as one of the identified key pathways for sustainable food transformation, with a focus on reduction of environmental impacts, biodiversity loss, GHG emissions, etc. (NPC 2021).

To address these interconnected challenges, a holistic approach is needed to evaluate and improve the sustainability of goat farming. Life cycle thinking provides such an approach by evaluating the environmental, social, and economic impacts across the entire life cycle of a product or service, from production to waste management. Life cycle sustainability assessment (LCSA) builds on this concept to quantify the resources and emissions generated, as well as the social and economic impacts, throughout a product's life cycle. LCSA encompasses three pillars of sustainability: environmental, economic, and social. Among these, life cycle assessment (LCA) is the most established standardized method (ISO 2006a, b) for quantifying potential environmental impacts. The ISO standard 14075 for social LCA has recently been published (ISO 2024), and it evaluates the social impact of a product or service during its life cycle. Considering the recentness of the social LCA ISO standards, most social LCA studies have used the UNEP/SETAC guidelines (UNEP 2020) when conducting social LCA. Life cycle costing method (LCC) assesses costs related to a certain product covered during its life cycle (Swarr et al. 2011). Together, these tools provide a framework for identifying opportunities to reduce resource use, minimize environmental impacts, and improve the social and economic performance of goat farming systems.

No LCA study on an agricultural product in Nepal has been published in the scientific literature. Given the significance of goat farming in Nepal's agricultural economy and rural livelihoods, this study aims to evaluate the sustainability of goat meat production in rural Nepal, and lay the ground for further sustainability assessment of agricultural products in Nepal and implementation of food system transformation policies (NPC 2021). Additionally, this study seeks to address the unique challenges of conducting a life cycle sustainability assessment (LCSA) study in a developing country context, where access to robust data is limited. By documenting these experiences and challenges, this study aims to provide valuable insights and lessons for future LCA studies in similar settings, ultimately supporting sustainable agricultural practices in Nepal and beyond.

2 Materials and methods

2.1 Scope definition

For the LCA, 1 kg of goat meat in carcass weight for human consumption produced in Western Nepal was selected as a functional unit. In this work, carcass weight refers to all parts of the goat sold generally in butcheries, including the carcass (body), legs, head, intestine, skin, internal organs, and blood.

Four goat production sites in two provinces in Western Nepal, namely, Dhangadi and Dadeldhura in Sudurpashchim Province and Surkhet and Dailekh in Karnali Province, were selected. Geographically, the selected areas cover low- and mid-hill regions. In addition, some cultivation data were collected in the lowland areas of Nepalgunj and Chitwan. In the selected production sites, goats are produced at farms of different sizes. In this study, we categorized the farms into three categories: household farms (< 15 goats), semicommercial farms (15–30 goats), and commercial farms (> 30 goats). In the selected regions, goats are raised for their meat, not for milk, hide, or labor purposes.

The system boundary is described in Fig. 1. Goat farming was included in the system, with inputs including feeds and fodder and salt and minerals for the goats and outputs including manure. Feed and fodder cultivation, including urea and other fertilizers, seeds, and machine work, were included. The feeds and fodders covered both local crops and grasses cultivated at farms, elsewhere in Nepal or abroad. Milling processes related to rice, wheat, and mustard were included. In some goat farms, ox was used as a draft animal for some field cultivation practices, but these processes were excluded from the system boundary. Some goats were bought and sold between farms for breeding purposes, which had an impact on the farms' economy, but the carbon footprint was not assessed for these animals. Goat transporters to the markets from the farmers, referred to here as middlemen, as well as butcheries, were within the system boundaries.

In environmental LCA, the carbon footprint was selected as an impact category to be studied. The IPCC 2021 GWP100, which is based on the IPCC 2013 method and was applied in SimaPro 9.6 within global characterization methods, was used (PRé Sustainability 2022). Emissions due to land use and land use change (LULUC) were excluded, as were CO_2 uptake and biogenic CO_2 emissions.

A simplified version of LCC was conducted due to limited data access and sensitive business data as well as due to its volatility, which differs according to the actors involved in the value chain. To keep the process simpler and prevent

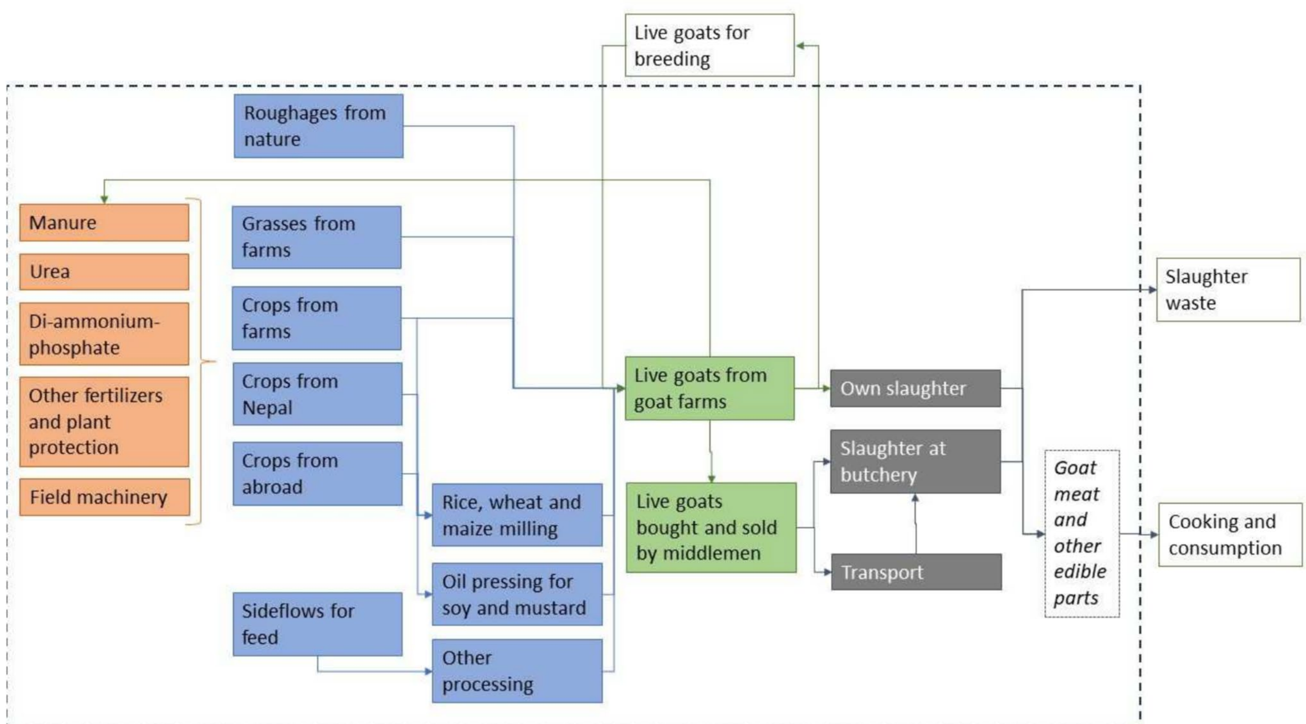

Fig. 1 System boundaries of the study

possible double counting of the impacts with the environmental and social aspects, the costing was performed via MS Excel.

The scope of the social LCA was limited to goat farms, where farmers and the head of a farmer group were interviewed. The analysis was conducted via the reference scales approach from the Handbook of Product Social Impact Assessment (PSIA) (Goedkoop et al. 2018). The impact categories were assessed and assigned a score based on the performance indicators and reference scales, with the following scoring system: − 2 = no data or non-compliant situation, − 1 = non-compliant situation but improvement, 0 = compliance with local laws, + 1 = progress beyond compliance, and + 2 = ideal compliance. By applying these reference scales, the social performance of the goat farming practices was quantified, highlighting areas of compliance and excellence, and identifying opportunities for improvement.

2.2 Life cycle inventory

Primary data for carbon footprint assessment and life cycle costing were collected from butcheries, middlemen, goat farms, cultivation farms, and local crop mills, and supporting data were obtained from local veterinarians and feed mill companies. Primary data collection for carbon footprint assessment, social LCA, and life cycle costing was executed as in-depth interviews with formal questionnaires from October 2023 to April 2024, for a total of 17 days in the field. Students from Far-Western University and Agriculture and Forestry University executed interviews on two data collection days. Goat farms of different sizes (household, semicommercial, and commercial) were selected for the interviews. In the semistructured interviews with key stakeholders, including goat farmers and heads of farmer groups, the interviews were conducted in Karnali (Dailekh, Surkhet) and Sudurpaschim provinces (Dhanghadi, Dadheldura). All the interviewees were volunteers. Data consent was obtained from single entrepreneurs who provided quantitative data. All primary data are considered confidential and managed according to the EU's GDPR legislation.

2.3 Primary environmental and cost data

In general, primary data from goat farms included the number of animals and the number of animals sold, all feeds and roughages (crop and mass), other inputs, and some general information on farm practices. If goat farms cultivated feed crops or grasses for goats at their own farm, the cultivation process was also included in the questionnaire. In terms of cultivation, the areas for certain crops, yields, and inputs were asked. If a goat farm did not know the yield for a certain feed crop or grass but was used totally for goats, all other information was still asked. The information asked from the crop mills was the share of different parts of the grain as a product from the mill, for example, the share of rice bran and husk.

The data were collected from four middlemen. One of them had a large business with approximately 50,000 goats sold per year. The other two sold 1000–5000 goats annually, whereas the fourth one sold 500 goats. The middleman data covered the number of animals bought and sold in different age groups, mortality and weight loss during long transport periods, and costs. Slaughtering data were collected from six butcheries. They either did the slaughtering themselves near the butcher shop or cooperated with a slaughterhouse slightly further. These data included the amount and share of parts of a goat's body sold separately and the costs and selling prices. Additional information was gathered from feed mills and local veterinarians.

The overall quality of the interview data was not sufficient. Table 1 presents the number of farms and other actors for which we were able to collect usable data and the total number of interviews. In terms of goat farms, the data rejection was, in most cases, due to a lack of basic

Table 1 Primary data interviews for environmental footprint and cost data. The bolded number indicates the number of farms or other actors from whom we obtained data usable in the environmental LCA modeling

	Dhangadi			Dhadeldura			Surkhet			Dailekh			Chitwan and Nepalgunj		
	CL	EA	LC	CL	EA	LC	CL	EA	LC	CL	EA	LC	CL	EA	LC
Household goat farms (< 15 goats)				2	2	0	6	0	0	2	2	0			
Semicommercial goat farms (15–30 goats)	1	0	0	1	1	0	1	1	0	1	1	0			
Commercial goat farms (> 30 goats)	7	6	6				2	1	1	2	2	2			
Crop cultivation (not goat farms)													5	5	0
Crop milling													2	2	0
Middlemen	1	1	1				3	3	3						
Butcheries	1	1	1				5	3	5						

CL – collected data, EA - used data for ELCA, LC – used data for LCC information on the number of sold animals or mass information on consumed feeds. In terms of butcheries, the two butcheries were rejected because the abnormal share between carcass weight and live weight was calculated according to the data acquired from them. Altogether, we obtained seven household and semicommercial goat farms and nine commercial farms. By crop cultivation farm data, we were able to cover rice (five farms), maize (five farms), wheat (two farms), and mustard (one farm) production.

Data on annual costs and income from selling live goats and meat were obtained from all the interviewees. The economic assessments of the farmers, butchers, and middlemen were evaluated separately with their own sets of data due to varying costs, rates, and transactions among different stakeholder groups (Table 1). However, the questions for the stakeholders were similar and included data related to the costs incurred during a year, including the acquisition of goats and other related costs incurred in the process of raising the goats (purchase of feed, regular medications, shelter management) and the staff employed for goat farming to income from selling the live goats or meat. On the basis of these datasets, the net income of each representative from each stakeholder category was calculated. The questionnaires used are provided in Supplementary B.

2.3.1 Secondary data for the carbon footprint assessment

The secondary data were collected from various sources. Data on the live weight of goats were collected in 2024 in two municipalities, Dullu and Bheriganga, in Karnali Province for cross, exotic, and local breeds in four separate age groups (Thakuri et al. 2024). These data were used as secondary data in the goat model used in this study. If machinery was used in the field, we assumed tillage by a tractor and applied secondary data for fuel consumption and emissions (EcoInvent 3). No emissions were allocated for grasses cultivated on the field sides with no specific inputs. Given the lack of information on grass cultivation at goat farms, we assumed that an area of one *kattha* would be dedicated to grasses and no inputs. The unit conversions are provided in Supplementary C (Table S1). Given that information for feed crops at goat farms is lacking, crop models for purchased feed crops were applied instead. The number of seeds (if not known) was assumed to be 95 kg/ha for annual grasses according to data from two farms. In the production of mustard cake, we assumed that the share of mustard cake was 70% mustard and that the nitrogen content was 4%. Rice straw was considered a side flow with no allocated emissions.

2.3.2 Social LCA data collection

The social LCA was conducted in two phases. In the first phase, a questionnaire with a 6-point Likert scale was developed to identify the social impact categories considered to be most important to the farmers. The Likert scale ranged from not important to extremely important, and a total of 80 respondents completed the questionnaire. However, owing to the language barriers and limited understanding of the local contexts, expert opinions, which were based on discussions with the farmers and field observations, were used to determine the important categories, which were further analyzed in the second phase.

For the second phase of social LCA data collection, semistructured interviews were conducted with key stakeholders, including goat farmers and one head of the farmers group. The different farmer groups interviewed were in Karnali and Sudurpaschim Provinces. In the Karnali Province (Dailekh and Surkhet), the interviews were conducted in the Chinchu, Dailekh Narayan, Naumule, and Naumule Ward 5 areas. In Sudurpaschim Province (Dhanghadi and Dadheldura), interviews were conducted in the Himalaya Krishi, Samuha Amargadhi, Samuha Dudhdhari, and Pragatisheel Dhangadhi areas. Each area represents an average of 20 goat farmers; however, in Chinchu, only the head of the farmer group was interviewed. The semistructured interviews were carried out via a developed questionnaire and were conducted in local languages with the help of interpreters. This allowed for flexibility, enabling participants to share their experiences and challenges to goat farming in their own words. However, this created certain challenges, as some concepts related to social impacts posed difficulty in translating directly. The questionnaire is provided in Supplementary A.

2.4 Modeling solutions

2.4.1 Goat farm model

For the goat farms, we modeled 1 year of livestock husbandry. The annual carbon footprint of goat farming on each of the farms was first calculated and then allocated per animal per month, including all goats (including the breeding animals). As the slaughter age varied, we allocated the environmental burden for each slaughtered goat by multiplying the carbon footprint per month per animal by its slaughter age in months.

We made certain assumptions to model the goat farms. First, the number of kids younger than 6 months at the farm was calculated according to the number of does. A value of 1.5 kids/doe/year was assumed. This assumption was made because of inadequate or contradictory data on most of the farms regarding the number of kids. Second, the goat farms produce live goats for four purposes: goats sold for meat purposes, for breeding purposes, for religious purposes, and for their own consumption. Here, we considered all the other purposes except for breeding, because the goats for religious purposes also end up for human consumption after the Hindu ritual of gifting the blood to God is completed.

The third assumption was related to manure. Manure is utilized on the fields as fertilizer. However, there are typically a number of different crop species, including table vegetables, cash crops, and grasses, for livestock cultivated at each farm, and annual crops harvested two to three times per year in each field plot. In addition to goats, other livestock animals are raised on many farms. Owing to the complexity of the system and the lack of accurate data on the exact use of goat manure per crop, we included all goat manure-related emissions in the goat production system, even though it was used for crops aimed at human consumption, not for goat feed.

As a fourth assumption, we expected some emission sources to be zero. Forests, as a source of roughage and grazing land, provide ecosystem services for goat production. All tree branches and grasses collected from nature were considered not to include any carbon footprint burden. In addition, if the farm reported grass production only on the sides of the field without any specific inputs given for them, it was considered fodder without any carbon footprint burden.

2.4.2 Feed production models

Each of the goat farms either cultivated their own feeds and fodders or bought them or both. We modeled the feed and fodder production at farms whenever there was own feed cultivation and included the feed and fodder production based on the primary data from the goat farm model.

Maize, rice, wheat, and mustard were assumed to be produced domestically in Nepal, and the models are based on data collected from Nepalese farms. We modeled wheat, maize, rice, and mustard on the basis of primary data. Data from two mills were used to model the shares of white rice, rice bran, and husk in rice milling. The allocation between mustard oil and cake was modeled according to the price information of these products in India acquired from the India Stat service (IndiaStat 2024a, b).

Secondary data were used for feed crops that were not covered by primary data, namely, soybeans, wheat bran, wheat flour, barley, and salt, and for all agricultural inputs. These feeds were modeled on the basis of secondary data describing Indian, global, or other parts of the world, according to data availability. Owing to the lack of secondary data, sugarcane molasses process data were used for jaggery, oat husk processes for wheat husk and lentil peels, and rice straw for maize straw and salt for minerals. These process data were acquired mostly from the EcoInvent 3 and Agri-Foodprint 5 databases.

2.4.3 Emission calculation

The IPCC Tier 1 methods and defaults were applied in most cases in emission calculations from crop and animal production. Table 2 presents the descriptive parameter values applied, and Table 3 presents the default parameter values applied. The formulas applied are listed in detail in the Supplementary C (Table S2). Methane emission from enteric fermentation was modeled by applying a default value of 5 kg CH_4/head/year as an emission factor (Table 3) with an underlying assumption of a live weight of 28 kg/animal (IPCC2019a, b, Table 10).

2.4.4 Middleman and butchery models

Middlemen operate at the local and regional levels. Only minimal transportation is needed for locally sold goats. However, goats are also transported to the larger cities of Kathmandu and Pokhara, especially from Karnali (Nepali et al. 2022). According to the interviews, animal transportation by truck from Surkhet in Karnali to Kathmandu took 24 h and to Pokhara 18 h. Three middlemen operating longer distances reported mortality rates ranging from 0.4 to 4%, and one local middleman reported 0.3% mortality during their processes. According to Nepali et al. (2022), 70% of the goats produced in Karnali and Sudurpaschim Provinces are sold to middlemen, and 60% of them are produced by regional traders, 42% of which are sold to the regional market. We assumed 1% mortality during live goat selling in total and long transportation of 550 km for 42% of the goats. In addition, weight loss in goats during long transport was reported by middlemen, but it was not included in the model.

The average slaughter age of commercial farms was 12 months, and that of household and semicommercial farms was 8 months. The average slaughter age of all the farms was 11 months. The share between goat live weight (LW) and carcass weight (CW) (including all parts of the animal sold in butcheries) was calculated from the butchery data, but owing to too high CW/LW ratio, we excluded two butcheries

Table 2 Descriptive parameters applied in modeling

Parameter	Value
Climate zone	Tropical
Climate type	Wet
Soil types	Low organic content
Manure management system	Dry lot
Productivity of goat farming	Low productivity

Table 3 Default values and assumptions in the emission calculation

Parameter	Value	Source
Enteric fermentation [kg CH_4/head/year]	5	IPCC 2019a, Table 10
Goat live weight [kg] (applied in manure management emission calculation)	24	IPCC 2019a, Table 10.A.5
Emission factor for CH_4 in manure management [kg CH_4/kg VS]	1.7	IPCC 2019a, Table 10.14
VS_rate [kg VS/1000 kg animal mass/day]	10.4	IPCC 2019a, Table 10.13
Nitrogen excretion [kg N/1000 kg animal mass/day]	0.34	IPCC 2019a, Table 10.19
Emission factor for N_2O in manure management [kg N_2O_N/kg N excretion]	0.02	IPCC 2019a, Table 10.21
FRACgasm in dry lot	0.3	IPCC 2019a, Table 10.22
FRACgasm in grazing	0.21	IPCC 2019b, Table 11.3
Emission factor EF4 [kg N_2O_N/(kg NH_3_N + NO_x_N)]	0.01	IPCC 2019b, Table 11.3
Emission factor EF5 [kg N_2O_N/kg N leaching and runoff]	0.011	IPCC 2019b, Table 11.3
FRACleach in dry lot	0.035	IPCC 2019a, Table 10.22
FRACleach in grazing	0.24	IPCC 2019b, Table 11.3
Emission factor EF1 for N inputs, synthetic fertilizer	0.016	IPCC 2019b, Table 11.3
Emission factor EF1 for N inputs, other	0.006	IPCC 2019b, Table 11.3
Emission factor EF3 for N deposit in grazing	0.003	IPCC 2019b, Table 11.3

Table 4 Consumed goat feeds and fodders

Feed type	Feeds and fodders specified
Grasses	Berseem, Napier, and other grasses
Tree branches	Ipil-ipil and other species of trees for branches
Rice	Rice, rice bran, rice husk, rice straw, and hay
Maize	Maize, maize flour, maize silage, and maize straw
Wheat	Wheat, wheat flour, wheat peels and wheat husk
Other grains	Soybeans, millet, barley
Side flows	Lentil peels, molasses, jaggery, and mustard cake
Salt and minerals	Salt and minerals

as outliers. The average CW/LW for the remaining four butcheries was 65%.

3 Results and discussion

3.1 Inventory analyses results

The farms differed from each other in terms of farm size and feeding and goat selling practices. The feeds and fodders consumed by the goat farms are presented in Table 4. The most important primary data on Nepalese rice, maize, wheat, and mustard production are compiled and presented in Table 5, and important primary data on goat feeding practices are presented in Table 6 and selling practices in Table 7.

3.2 Carbon footprint results

The carbon footprint, assessed per kg carcass weight of goats separately for each farm, was on average 17 kg CO_2eq/kg CW (Table 8., Fig. 2). Methane emission from enteric fermentation was the most important factor contributing to the

Table 6 Background primary data on goat farming

Feeding practices in goat farms	Number of farms (out of 16)
Grazing, as part of the diet	12
Tree branches collected from nature	14
Grasses collected from nature	7
Grasses cultivated at farm	13
Other feed crops cultivated at farm	8

Table 5 The most important key figures from the primary data on Nepalese rice, maize, wheat, and mustard production

	Rice	Maize	Wheat	Mustard
Average area [ha]	2.8	0.8	0.3	0.2
Average yield [kg/ha]	4200	3600	2700	1200
Average urea application[kg/ha]	35	66	180	0
Average di-ammonium-phosphate application[kg/ha]	101	54	134	0
Average organic N application [kg N/ha]	109	80	90	48

Table 7 Total number of goats at the farm, total live weight (LW) of sold goats in kg, and the relative shares of LWs sold in different age groups

Province	Farm size	Farm	Total number of goats	Goats sold/total number of goats	Sold LW kg, total	Sold LW %: 4–9 months	Sold LW %: 10–13 months	Sold LW %: 14–18 months	Sold LW %: older
Sudurpashchim	Household	Farm A	5	21%	20	0%	100%	0%	0%
		Farm B	7	28%	15	100%	0%	0%	0%
	Semicommercial	Farm C	17	12%	15	100%	0%	0%	0%
	Commercial	Farm D	133	33%	914	10%	0%	90%	0%
		Farm E	56	48%	479	11%	89%	0%	0%
		Farm F	57	37%	485	12%	12%	60%	16%
		Farm G	63	62%	1075	0%	73%	0%	27%
		Farm H	35	23%	196	0%	100%	0%	0%
		Farm I	89	32%	716	16%	12%	0%	73%
Karnali	Household	Farm J	15	21%	34	46%	54%	0%	0%
	Semicommercial	Farm K	36	14%	96	8%	39%	53%	0%
		Farm L	86	21%	164	100%	0%	0%	0%
	Commercial	Farm M	170	35%	475	100%	0%	0%	0%
		Farm N	45	14%	95	33%	0%	67%	0%
		Farm O	59	98%	516	100%	0%	0%	0%

Table 8. Carbon footprint results for goat meat (CW) originating from different farms

	Average	Median	Min	Max	Standard deviation
kg CO_2eq/kg CW	17.1	16.9	11.4	23.0	3.2

total carbon footprint, accounting for 52–75% of total emissions. Manure management was another important factor, and rice as a feed crop in some cases. However, the cultivation of other feed crops had only a minor role, and the animal transportation operated by middlemen had a negligible impact.

However, in this study, a default emission factor for enteric fermentation was applied (Table 3); therefore, only productivity (kg CW/number of goats) differentiated the farms. The same applies to methane emissions from manure because the default nitrogen excretion rate was applied to all the animals (Table 3), and a similar type of manure management system (dry lot) was applied to all the goat farms. The highest carbon footprint was assessed for goat meat originating from farms B, C, M, L, E, and O. In five of these farms (B, C, M, L, and O), 100% of the goats sold during the study period were very young, ranging from 4 to 9 months (Table 7), and many approximately 4-month-old goats were used in religious rituals. The amount of carcass weight acquired from young goats is naturally relatively low. However, the methane emissions from both enteric fermentation and manure may be slightly overestimated, especially for young goats, when default emission factors are applied.

The goat meat from farms H, I, F, K, N, and A had the lowest carbon footprint. Among these farms, farms H and A sold their goats at the age of 10–13 months, and farms K and N sold goats mostly at the age of 10–18 months (Table 7). However, the slaughter age is not the only explanation for the lower carbon footprint, as farm I also had a low carbon footprint even though it sold the majority of its goats as relatively old (> 18 months), and farm F sold goats of all ages (Table 7).

Feed production had only a minor impact. Rice bran is an exception. For example, in farm G, the share of rice bran was high (80% of the diet excluding roughage), contributing to 30% of the total carbon footprint of a product. The relatively small contributions of the other feeds were due to several factors. First, most of the goat farms either use pastures as a part of their feed or collect grasses and tree branches from nature (Table 6). Second, grass cultivation is very extensive in the case areas: the application of nutrient inputs was very low. Third, the cultivation of other feed crops was also managed with relatively low levels of fertilizers. Finally, straw, jaggery, and other available feed compounds based on side flows also play important roles in feeding.

3.3 LCC results

The net annual income for semicommercial and commercial farms is presented in Fig. 3, along with the carbon footprint results. The relative average net annual income in the chain, including semi-commercial and commercial farms, middlemen, and butcheries, is presented in Fig. 4.

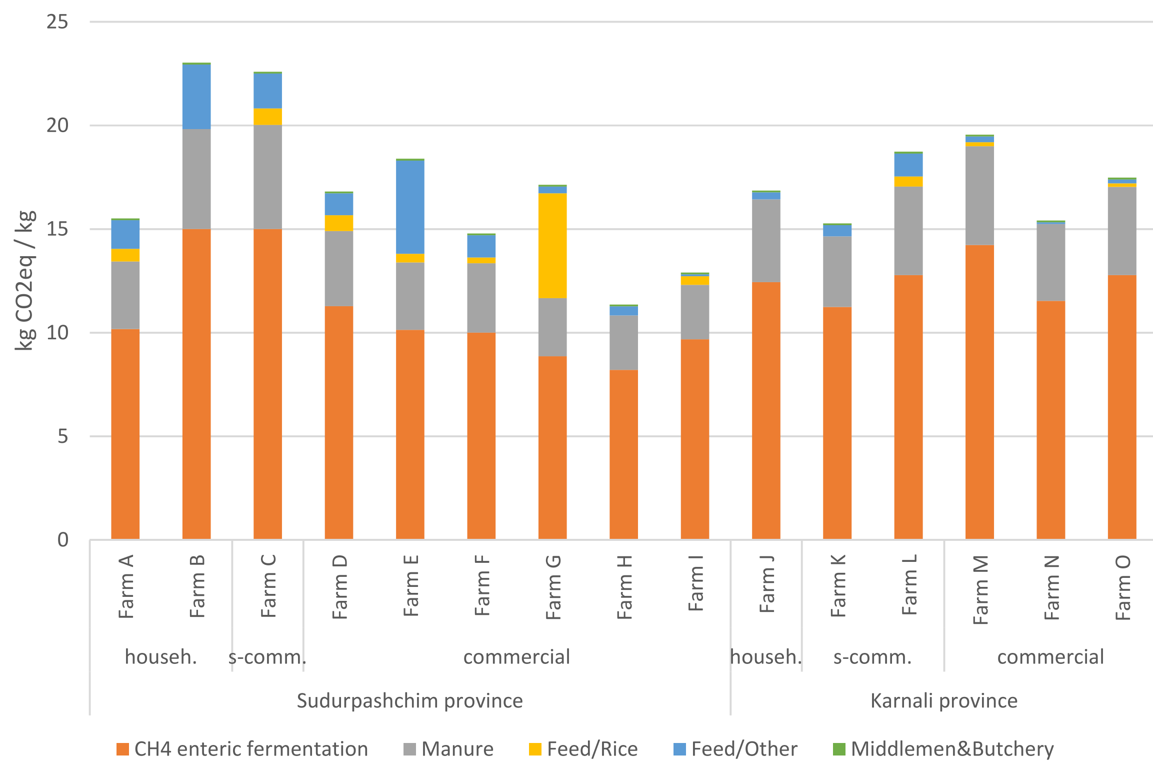

Fig. 2 The carbon footprint (kg fossil and biogenic CO_2eq) of goat carcass weight from household (*househ.*), semicommercial (*s-comm.*) and commercial farms in Sudurpashchim and Karnali Provinces sold in butcheries

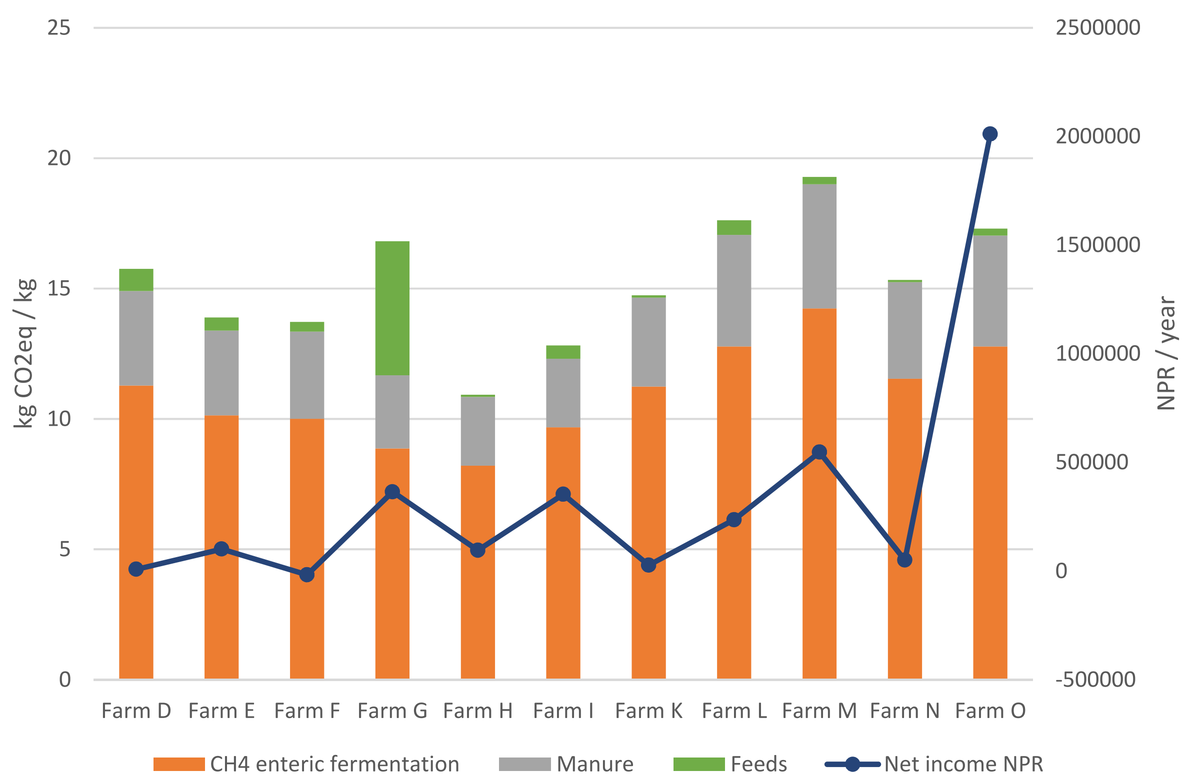

Fig. 3 Net annual income for semicommercial and commercial farms and related carbon footprints

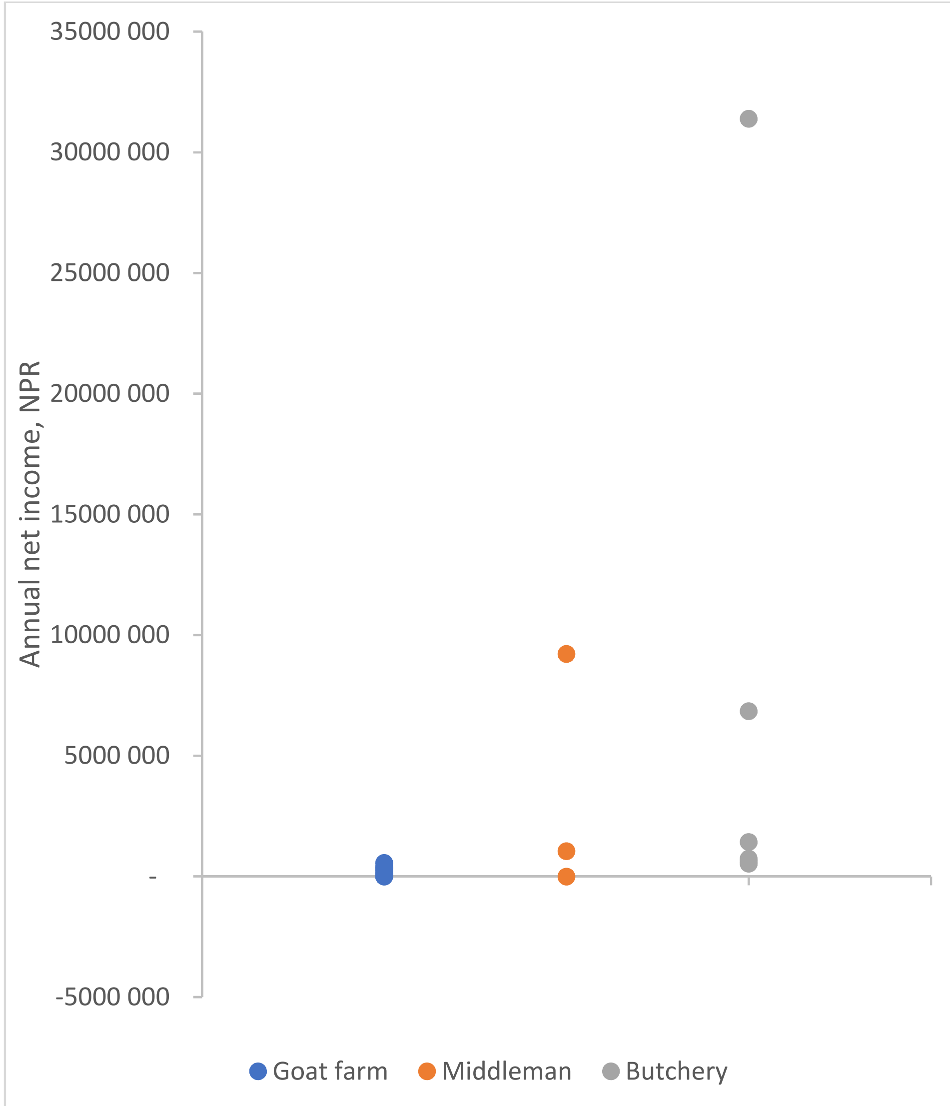

Fig. 4 Net annual income of semi-commercial and commercial farms, middlemen, and butcheries in Nepalese Rupees (NPR)

The results indicate that, in general, the goat business is a good business, but profitability is mostly toward the downstream side of the value chain. The logistics business of middlemen of transferring goats from producers to sellers and butchers selling directly to the customers looks economically promising. However, the differences between the individual firms within the stakeholder group are remarkable. The economic inconsistency is clearly visible among the stakeholders in Fig. 4. The farmers seem to be barely managing in comparison to other stakeholder categories, with one exception shown by farm O (Fig. 3). Farm O was able to sell all its goats during our data collection time, which led us to these exceptional profitability numbers. Besides farm O, among the remaining 11 farms represented in Fig. 3, four farms are just above the 0 line, whereas the rest are either on the zero-income line or in loss below zero. This inconsistency in the profitability range of the stakeholders highlights the key issue of a lack of implementation of price margins in the goat business markets.

Business profitability was significantly dependent on the timing and purpose of the selling of goats to the farmers. The results revealed that the farms that sold goats for breeding purposes, especially early-age goats starting from 4 to 9 months of age, made the greatest profit in comparison to the farms that sold more meat and those in which the goats were slightly older. One reason could be the pricing of goats, as those sold for breeding purposes are priced better than those sold for meat.

3.4 Social LCA results

As mentioned in Sect. 2.3.1.3.1, the social LCA was conducted in two phases. In the first phase, certain social impact subcategories were considered to be the most important according to expert opinions formed from interviews with farmers and the head of a farmer group. These impact subcategories fit into the small-scale entrepreneur category from the handbook of PSIA and include "meeting basic needs," "access to services and inputs," "women's empowerment," "child labor," "land rights," and "fair trading relationships."

On this basis, social LCA was conducted via the reference scales approach from the Handbook of Product Social Impact Assessment (PSIA), as discussed in Sect. 2.1. The results for the areas in Karnali Province (Chinchu, Dailekh Narayan, Naumule, and Naumule Ward 5) and Sudurpaschim Province (Himalaya Krishi, Samuha Amargadhi, Samuha Dudhdhari, and Pragatisheel Dhangadhi) are shown in Figs. 5 and 6, respectively. The results assess how these subcategories shape the social sustainability of small-scale goat farmers in these provinces.

In Karnali Province, the results for the subcategory "meeting basic needs" vary among the different areas in the province. Only in Naumule Ward 5 have there been awareness-raising programs targeting small-scale entrepreneurs' basic needs, and the entrepreneurs find these interventions useful. In the other areas, Chinchu, Dailekh Narayan, and Naumule, a majority of the small-scale entrepreneurs do not have access to safe drinking water or improved sanitation facilities. Additionally, most small-scale entrepreneurs feel that they do not have a sufficient food supply throughout the year. While there have been some interventions to improve current conditions in Dailekh Narayan and Naumule, basic

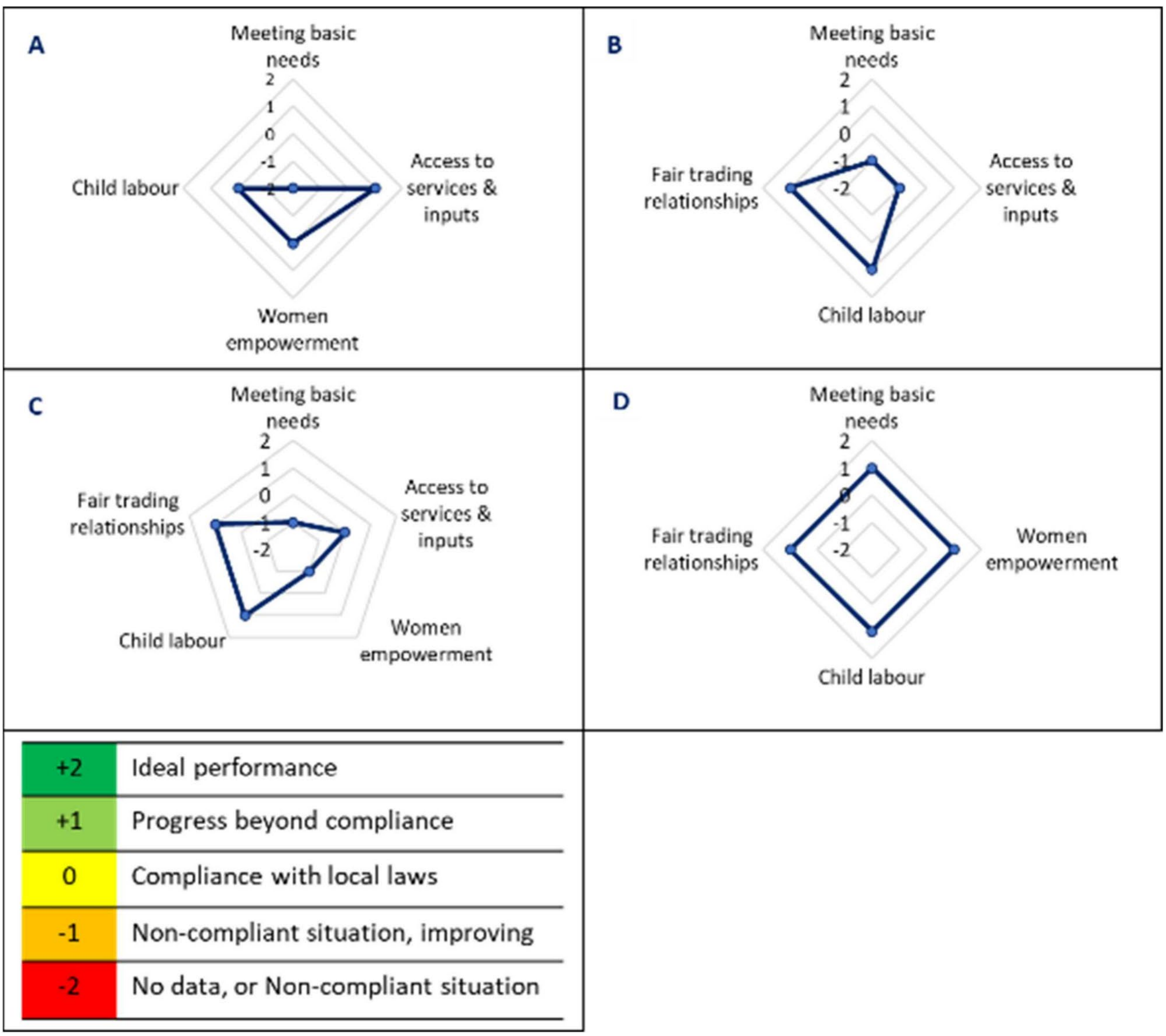

Fig. 5 Social impact assessment results for the small-scale entrepreneur category for different farmer groups in Karnali Province: **A** Chinchu, **B** Dailekh Narayan, **C** Naumule, **D** Naumule Ward 5

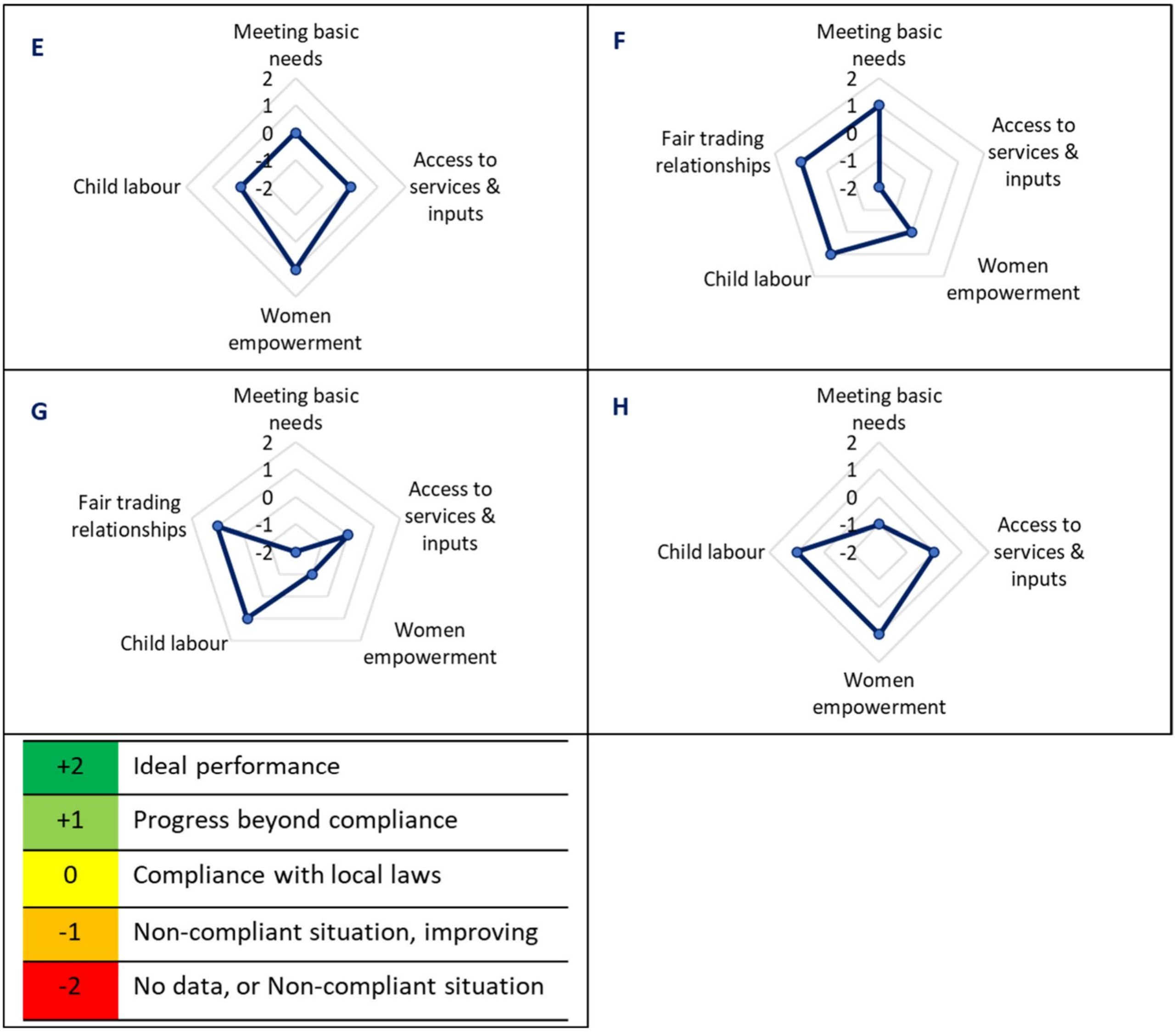

Fig. 6 Social impact assessment results for the small-scale entrepreneur category for different farmer groups in Sudurpaschim Province: **E** Himalaya Krishi, **F** Samuha Amargadhi, **G** Samuha Dudhdhari, **H** Pragatisheel Dhangadhi

needs are still not met. For Chinchu, opportunities for improvement have yet to be identified.

On the other hand, regarding "access to services and inputs," only in the Chinchu area do we have a majority of the entrepreneurs satisfied with the services and inputs offered, such as bank loans and goat feeds. Although there is a compliant situation where interventions are undertaken to improve access to services and inputs in Naumule, in Dailekh Narayan, there is limited access to services and inputs and limited data in Naumule Ward 5 to draw conclusions.

In the "women's empowerment" subcategory, the women in Naumule Ward 5 find the empowerment programs useful and correspond to their interests and needs, whereas in Chinchu, the role of female small-scale entrepreneurs is evaluated and recognized within the value chain. Female small-scale entrepreneurs have equal rights and opportunities to provide interventions, and activities tailored to enhancing women's empowerment are promoted and carried out. However, in Naumule, the role of female small-scale entrepreneurs is evaluated and recognized, but activities tailored to enhancing women's empowerment are not promoted and carried out.

In the "fair trading relationships" subcategory, the areas within Karnali Province have recognized the actions taken to encourage entrepreneurs to join cooperatives for improved fair trading. This is because most farmers do not have direct access to markets and thus sell through middlemen, who offer lower prices for farm products. Farmers from more remote areas face high transportation costs, which further reduce their profits, thus leading to struggles to secure fair prices for their goats. Thus, encouraging these farmers to join cooperatives could help them access better markets and achieve more equitable trading relationships. Additionally, connecting farmers directly to buyers can increase transparency and ensure fairer prices for farmers. With respect to the "child labor" subcategory, no child labor is detected, as most children receive school education, which mitigates the risk of child labor.

In Sudurpaschim Province (Himalaya Krishi, Samuha Amargadhi, Samuha Dudhdhari, and Pragatisheel Dhangadhi), the results for the subcategory "meeting basic needs" also vary significantly between the different areas in the province. While actions targeting small-scale entrepreneurs' basic needs are undertaken (awareness-raising programs, best practices) in Samuha Amargadhi and the people find the interventions useful, the goals of the goat farmers in Pragatisheel Dhangadhi recognize that interventions to improve current conditions are undertaken, but the basic needs are still not met. In Samuha Dudhdhari, data limitations prevented the ability to draw conclusions.

With respect to the subcategory "access to services and inputs," all the areas except Samuha Dudhdhari found that interventions are undertaken to improve small-scale entrepreneurs' access to services and inputs. However, there are limited data to draw conclusions in Samuha Dudhdhari.

In the "women empowerment" subcategory, the women in Himalaya Krishi and Pragatisheel Dhangadhi find the offered activities useful and correspond to their needs and interests, whereas women in Samuha Amargadhi are aware that the role of female small-scale entrepreneurs is recognized, but that activities tailored to enhancing women's empowerment are not promoted and carried out.

Finally, in the "fair trading relationships" and "child labor" subcategories, the results align with those of the Karnali province, where actions are taken to encourage entrepreneurs to join cooperatives for improved fair trading, and no child labor is detected, as most children receive school education, which mitigates the risk of child labor.

Generally, there is an uneven distribution of interventions, especially regarding "meeting basic needs," "access to services and inputs," and "women empowerment." There is a need for area-specific strategies; for instance, areas such as Chinchu, Dailekh Narayan, Naumule, Samuha Dudhdhari, and Pragatisheel Dhangadhi, which lack identified opportunities for improvement in meeting basic needs, could benefit from similar awareness programs or best practices successfully implemented in Naumule Ward 5 and Samuha Amargadhi. This could be applied for other impact subcategories. Regarding "access to services and inputs" in areas where there are significant gaps with limited data preventing a thorough understanding of intervention effectiveness, there requires better data collection and program monitoring to ensure interventions effectively address the needs of the farmers. The challenges surrounding "fair trading relationships" is quite consistent across both provinces, with farmers relying on middlemen due to limitations in accessing the market directly. This arrangement often results in lower prices and reduced profits, especially for farmers in remote areas facing high transportation costs. Establishing direct links between farmers and buyers can enhance transparency and ensure equitable trading relationships and reduce dependency on middlemen. Furthermore, the absence of child labour across the two provinces is an encouraging finding, largely attributed to the widespread school attendance among children. Sustaining and expanding access to quality education will be essential to ensuring that this positive trend continues.

4 Lessons learnt and future possibilities

As a process, life cycle sustainability assessment for goat meat in Nepal is feasible but challenging. The production systems are very holistic; for example, intercropping and crop rotation are generally applied, and rearing several different livestock at one farm is a common practice. For the environmental LCA and LCC, the individual interviews of farmers and entrepreneurs were selected as a method for data collection. The personal interviews made it possible to explain the questions and clarify the answers. However, the complexity of the systems and the lack of records from the goat farmers and entrepreneurs increased the uncertainty and inaccuracy of the answers.

For the life cycle costing analyses, the data should be collected with a larger number of stakeholders involved and a longer data collection time. A group interview ensures the consistency of the economic data we received. At the farm level, more detailed cost and income data should be collected over a longer period to ensure reliability, since the data collected across the farms varied greatly and seemed inconsistent even in close locations.

In general, the focus on a single year was a limitation, which may not fully reflect the natural variations in agricultural processes, income, and labor demands. However, this serves as a good learning point for future studies to better capture these dynamics and improve data accuracy. As no record keeping exists, especially for agricultural farms, the only practical way to collect data over several years is to interview the same farms over many years. Owing to the lack of previous studies, much effort is needed to collect primary data, but this would gradually improve if more life cycle sustainability studies are published in Nepal.

For social LCA, group discussions with farmer groups seemed to be a practical way to obtain an overall picture of the social issues related to goat production because the group members were familiar with one another and were able to talk more freely. However, for more in-depth analyses, more detailed interviews would have been needed to complement the general analyses. Additionally, while these results provide good insights into the social sustainability of small-scale goat entrepreneurs in the provinces of Sudurpaschim and Karnali in Western Nepal, there are challenges related to the quality of the data collected due to the limited information provided, the language barrier, and the informal nature of many farming practices. With respect to methodology limitations, working with a 5-point scale oversimplifies the complexities of real-life situations, and the results may mistakenly be seen as representing proportional differences, which is not the case (Goedkoop et al. 2018). For future SLCA studies, the questionnaire should be aligned very well with the target stakeholders and the context where they are located. This would help us identify the basics of the local context beforehand, which would lead the focus of the data to more important aspects of society and stakeholders.

For future studies, we identified some further research needs. A deeper analysis of social and economic impacts along the whole chain is needed. There is a need to develop and modify stakeholder impact categories, subcategories, and indicators to fit into the informal agricultural sector for a more inclusive social sustainability assessment and improvements. As suggested by previous studies (Neupane et al. 2018; Panth et al. 2021), the limited access to the market, lack of commercialization and market knowledge, and strengthening of the live animals selling markets should be assured to support the farmers in getting fair prices and market access. From the economic perspective, goat farming and the overall goat meat business in Nepal is a flourishing business with continuously growing demand and market. The goat farming seems to be an attractive and growing source of income in Nepal in the Sudurpaschim and Karnali regions. The demand has been competitively increasing with an annual growth rate of 4%, but poor management practices, genetic inferiority of local breeds, and lack of proper health services for better producing crossbred animals has led to lesser production (Neupane et al. 2018).However, it would be more efficient and beneficial for all the stakeholders involved, especially the farmers, if price control can be applied to the rates and prices for purchase and sale of goats by the government. This would help stabilize the prices across the country, as well as encourage the farmers, and meat products would be accessible to the consumers at fair prices.

With respect to the carbon footprint, the methane emissions from both enteric fermentation and manure management are crucial, and further studies on these emissions are needed. To date, the default Tier 1 factors provided by the IPCC (Table 3) to assess methane emissions have been applied. However, methane from enteric fermentation of a goat depends, e.g., on the goats' size and diet. In the study by Thakuri et al. (2024), the country-specific emission factors for enteric fermentation of goats ranged from 2.3 to 8.1 kg CH4 head^{-1} year^{-1} in Nepal according to the breed type and age, and those for manure management ranged from 0.03 to 0.32 kg CH4 head^{-1} year^{-1} accordingly. Modeling the age groups and different breeds of each farm in more detail would enable the application of these IPCC Tier 2 emission factors for more precise results.

In life cycle assessment, the impacts are studied in relation to the functional unit (kg carcass weight); therefore, the overall efficiency of the goat meat production chain affects the level of impact. We identified several points in the chain affecting overall efficiency. The age of goats at the time of slaughtering is important and should be studied further to determine the optimum age for slaughtering in terms of animal growth. It is obvious that goats (excluding breeding animals) should not be kept after they have reached a certain size for economic and environmental reasons, and the results of this study showed that slaughtering at very young ages increases the carbon footprint as well. The slaughter age varied between farms and was generally lower for the household and semicommercial farms than for the commercial farms. However, the demand for goat meat is focused on festival seasons, challenging the production system, and it seems that the middlemen system does not always work optimally, as some farmers reported difficulties selling goats. More scientific evidence and deeper knowledge on the reasoning behind current practices and the dynamics of the production chain are needed to develop improvement actions.

A remarkable weight loss of animals during transportation was reported, as well as mortality. Only mortality was taken into account in the carbon footprint modelling in this study, and animal transportation did not play an important role in the results. The weight loss should be studied further with wider data to understand if it is temporal or does it affect the amount of meat, having an effect on the overall results. Nevertheless, long transports are an important animal welfare issue, and the practices should be improved in that perspective anyway.

In general, the effect of natural pastures should be considered more carefully, because the majority of the goat farms in the studied regions rely on natural pastureland, in at least some extent. Pardo et al. (2023) suggest taking also wild ruminants into account within LCA in the future, whenever livestock relies on natural ecosystems. A comprehensive research would be needed to study the positive and negative impacts of goats' grazing on natural pasturelands, not only greenhouse gas emissions but also impacts on biodiversity.

Shah et al. (2023) reported a shortage of forage materials and reported great variation in the availability and nutrient content of popular fodder trees in mid-hills of Nepal. In addition, breeding and selecting breeds are highly important (Kosgey & Okeyo 2007). Therefore, developing feeding practices and animal health and selecting breeds suitable for the conditions available might improve the environmental performance of goat production and the economy of goat farmers, especially those who are selling mainly for meat purposes, not for breeding. It might also support them in meeting basic needs, which is considered one of the hotspots in the social LCA. Life cycle sustainability assessment could be utilized as a tool to study the effects of these potential interventions.

Applying a life cycle sustainability assessment for a food product in Nepal would provide many benefits and possibilities in the future for the agriculture and food sector, political decision-making, targeted subsidies, targeted development actions by the government and organizations, and new research. These kinds of studies would also help in reaching out to the issues highlighted as the key drivers of the unsustainable food production system in Nepal by NPC 2021, like climate change impacts, land use and land use changes, socio-economic changes like urbanization, changing diets and consumption, and poor market price regulations. Life cycle assessment is a multidisciplinary approach; therefore, it may bring researchers and experts from different disciplines together with farmers and entrepreneurs to share their knowledge and expertise and generate new knowledge and ideas.

5 Conclusion

The findings highlight the importance of improving the overall production chain efficiency to decrease the carbon footprint, increase economic profitability for farmers, and yield positive social impacts.

The carbon footprint of goat meat produced in Western Nepal was 17 kg CO2eq/kg CW, with enteric fermentation being the largest contributor to emissions, followed by manure management. The importance of feeds was relatively low, due to the high share of nature-based feeds and feeds produced with only a minimum amount of external inputs. In future studies, applying more specific methods to assess enteric fermentation would give better insights into the underlying reasoning, but requires more specific data from farms.

Despite high market demand, the farmers are not able to make the best of goat farming. The farmers do not have direct market access and have limited live animal selling markets; thus, they are highly dependent on middlemen and traders for sales. Instead, middlemen and butchers seem to get a good annual income from the goat business.

The comparative social life cycle assessment of Karnali and Sudurpaschim Provinces in Western Nepal highlighted the importance of region-specific approaches. While certain interventions have been identified in specific areas, their inconsistent implementation across regions suggests a need for better coordination and scaling of successful practices. The social LCA findings also emphasized the interconnected nature of the impact subcategories. For example, addressing unmet basic needs, such as food security, can enhance the productivity and profitability of goat farming, thereby improving access to markets and limiting reliance on middlemen, thereby promoting fair trading practices. Similarly, empowering women can lead to broader community benefits, given their central role in managing goat farming activities.

This study marks the first application of life cycle sustainability assessment (LCSA) to goat meat in Western Nepal, demonstrating that despite the absence of comprehensive existing data, conducting an LCSA is feasible through the collection and utilization of primary data. However, collecting primary data is time-consuming, and due to complex systems, careful familiarization with the actual processes is needed. The results of this study can also support in the implementation of the action area “manage sustainably existing food production systems” with a focus on sustainable livestock production highlighted by the Government of Nepal NCP’s food system transformation dialogues as part of the UN food systems summit 2021 (NPC 2021).

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Author contribution Conceptualization: Kirsi Usva, Ira Bhattarai, Mariam Abdulkareem; methodology E-LCA: Kirsi Usva; methodology LCC: Ira Bhattarai; methodology social LCA: Mariam Abdulkareem; data collection: Kirsi Usva, Ira Bhattarai, Kisun Pokharel, Madan Sapkota, Sunita Panthi, Pushpa Acharya, Raksha Sharma; formal analysis and investigation: Kirsi Usva, Ira Bhattarai, Mariam Abdulkareem; support in modelling solutions: Pushpa Acharya, Madan Sapkota, Kisun Pokharel, Sunita Panthi, Raksha Sharma; writing—original draft preparation: Kirsi Usva, Ira Bhattarai, Mariam Abdulkareem, Sunita Panthi.

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Data availability The authors declare that the data supporting the findings of this study are available within the paper and its supplementary information files. Primary data from individual farmers and entrepreneurs is not available due to confidentiality issues.

Declarations

Competing interests The authors declare no competing interests.

References

Thakuri Sudeep, Ghimire Shiba Raj, Acharya, Pushpa Raj, Baskota Preshika, Sapkota Madan Mani, Aryal Kamal, Maharjan Bishnu (2024) CH_4 emission from enteric fermentation and manure management of domestic goats in Nepal. Poster available in https://www.icimod.org/adaptation-solutions-portal/images/action-research/Grape_poster__finalset_forprint-pages-20.pdf.

Goedkoop MJ, Indrane D, de Beer IM (2018) Product social impact assessment handbook – 2018, Amersfoort.

IndiaStat, (2024) Selected state/centre-wise monthly wholesale prices of mustard cake in India (2022). Electronic Data Delivered Due to Personal Request 5(9):2024

IndiaStat, (2024) Selected state/centre-wise monthly wholesale prices of mustard oil in India (2022). Electronic Data Delivered Due to Personal Request 5(9):2024

IPCC (2019a) Chapter 10: Emissions from livestock and manure management. Volume 4: Agri-culture, Forestry and Other Land Use. 2019 Refine-ment to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Volume4/19R_V4_Ch10_Livestock.pdf

IPCC 2019b. Chapter 11: N2O emissions from managed soils, and CO2 emissions from lime and urea application. Volume 4: Agriculture, Forestry and Other Land Use. 2019 Refine-ment to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/4_Vol-ume4/19R_V4_Ch11_Soils_N2O_CO2.pdf

ISO 2006a. ISO 14040:2006 Environmental management — life cycle assessment — principles and framework. International Organisation for Standardisation.

ISO (2006b) . ISO 14044:2006 Environmental management – life cycle assessment – requirements and guidelines. International Organisation for Standardisation.

ISO 2024. ISO 14075:2024 Environmenal managment - principles and framework for social life cycle assessment. International Organisation for Standardisation.

Jaisi M, Subedi R, Dhital B, Neupane H, Khanal A, Kattel P. Research, D. of. (2016). Livelihood assessment report: Gorkha recovery and resilience program, Nepal. Technical Advisory Service Project. Kathmandu: Institute of Agriculture and Animal Science.

Kosgey IS & Okeyo AM (2007). Genetic improvement of small ruminants in low-input, smallholder production systems: technical and infrastructural issues. Small Ruminant Research, 70(1), 76–88.

Maharjan A, Bauer S, & Knerr B (2013). Migration for labour and its impact on farm production in Nepal. Working Paper IV. Battisputali, Kathmandu: Centre for the Study of Labour and Mobility.

Massé Daniel I, et al (2016) "Effect of increasing levels of corn silage in an alfalfa-based dairy cow diet and of manure management practices on manure fugitive methane emissions." Agriculture, Ecosystems & Environment 221: 109–114.

Mazhangara I, Rumbidzai; Chivandi, Eliton; Fisher Mupangwa, John and Muchenje, Voster. (2019) The potential of goat meat in the red meat industry. Sustainability 11(13):3671. https://doi.org/10.3390/su11133671

MoALD 2023. Statistical information on Nepalese agriculture 2078/79 (2021/22). Ministry of Agriculture and Livestock Development, Singhadurbar, Kathmandu.

MoSTE 2014. Nepal second national communication to United Nations framework convention on climate change. Ministry of Science, Technology and Environment, Kathmandu, Nepal.

Nepali N, Adhikari A, Nyachhyon A, Prajapati A, Kothari R, Bhatta S, Thapa M (2022) Rapid assessment of agricultural value chains in Sudurpaschim and Karnali province. iDE Nepal for GIZ/GRAPE/LPED. July 2022. Available at: https://www.giz.de/de/downloads/giz2022-en-rapid-assessment-of-agriculture-value-chains.pdf

Neupane N, Neupane H, Dhital B (2018) A socioeconomic view of status and prospects of goat farming in rural areas of Nepal. Inst Agric Anim Sci 35:1–8

NPC (National Planning Commission of Nepal). 2021. Nepal's food systems transformation: context, pathways and actions. Outcomes of the National and Provincial Food Systems Dialogues as a part of the UN Food Systems Summit 2021. National Planning Commission, Singha Durbar, Kathmandu, Nepal

NSO. 2023. National Sample Census of Agriculture Nepal 2021/22. National Statistics Office, Kathmandu, Nepal.

Panth B, Prasad; Bhattarai, Nirajan; Baral, Puja; Karki, Mahesh; Bhattarai, Anita & Sapkota, Saroj, (2021) Factors affecting the profitability from goat farming in Gulmi. Nepal, Cogent Food & Agriculture 7(1):1963928. https://doi.org/10.1080/23311932.2021.1963928

PRé Sustainability. 2022. SimaPro database manual methods library. Database & Support team at PRé Sustainability. Available at: https://simapro.com/wp-content/uploads/2022/07/DatabaseManualMethods.pdf

Rana Dipendra, Paudel Samyog, Chaudhary Gopal, Pokhrel Abiskar, Bhandari Santosh, Sharma Surya Prasad (2022) Performance of locally adopted goats in Sundarbazar Municipality of Lamjung District, Nepal. Complexity, vol. 2022, Article ID 1946125, 6 pages. https://doi.org/10.1155/2022/1946125

Ricci P, Rooke JA, Nevison I, Waterhouse A (2013) Methane emissions from beef and dairy cattle: quantifying the effect of physiological stage and diet characteristics. J Anim Sci 91(11):5379–5389. https://doi.org/10.2527/jas.2013-6544

Sapkota, S., Gairhe S., Upadhyaya N., Acharya Y., Kadel R. and Malla S. 2021. Status and prospect of goat meat production in Nepal. Proceedings of 12th National Workshop on Livestock and Fisheries Research in Nepal, 3–4 March, 2021. Nepal Agricultural Research Council, Kathmandu, Nepal.

Shah M, Kumar; Pandey, Luma Nidhi; Bastola, Rupa; Shah, Bimala; Shah, Shatrughan. (2023) Goat feed resources and feeding management in mid-hill of Nepal. Int J Appl Sci Biotechnol 11(1):15–24. https://doi.org/10.3126/ijasbt.v11i1.53701

Swarr T, Hunkeler D, Klöpffer W, Pesonen H-L, Ciroth A, Brent A, Pagan R (2011) Environmental life-cycle costing: a code of practice. The International Journal of Life Cycle Assessment 16:389–391. https://doi.org/10.1007/s11367-011-0287-5

UNEP. (2020) Guidelines for social life cycle assessment of products and organizations 2020. Benoît Norris C, Traverso M, Neugebauer S, Ekener E, Schaubroeck T, Russo Garrido S, Berger M, Valdivia S, Lehmann A, Finkbeiner M, Arcese G (eds.). United Nations Environment Programme (UNEP).

Wei Ying, Zhang Xue, Xu Meijia, Chang Yuan (2023) Greenhouse gas emissions of meat products in China: a provincial-level quantification. Resources, Conservation and Recycling, 190, 2023, 106843, ISSN 0921–3449, https://doi.org/10.1016/j.resconrec.2022.106843.