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Estimating the environmental impact of the Regeneration of Landscapes and Livelihoods (ROLL) project in Lesotho

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Background

This assessment was undertaken as part of the Low Carbon and Resilient Livestock Development Strategies for Climate Informed Investments project,[1] jointly implemented by the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD). The project aims to support IFAD-funded projects in Kyrgyzstan (Özkan, Mottet and Mundy, 2021), Lesotho, Rwanda and Tajikistan to develop and implement strategies that will improve livestock production, while reducing greenhouse gas (GHG) emissions and improving the resilience of farmers, as part of the second phase of the Adaptation for Smallholder Agriculture Programme (ASAP2).[2] This report presents the impact of the ROLL project (Box 1) on GHG emissions, in addition to better poverty reduction and food security associated with sheep produced mainly for wool, goats produced mainly for mohair, dairy goats, meat goats, chicken layers and hatcheries, as covered in the ROLL project. It also provides recommendations for livestock investment to improve production efficiency while reducing absolute emissions and/or emission intensity.

The assessment was carried out using the Global Livestock Environmental Assessment Model – *interactive* (GLEAM-*i*) tool, developed by FAO to measure emissions from livestock value chains and to compare the impact of future scenarios. The guidelines (FAO, 2021), as well as links to technical videos that provide in-depth information about how to use the tool, can be found on the GLEAM page. [3] The three major GHGs covered in the tool are methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) (Table 1). The global warming potentials (GWPs) used to convert CH_4 and N_2O to CO_2 equivalents (CO_2e) are 34 and 298, respectively, according to the Intergovernmental Panel on Climate Change (IPCC) guidelines (Myhre *et al*., 2013). GLEAM-*i* covers life-cycle emissions from the production of inputs up to the farm gate. Details of the emission sources can be found in the model description (FAO, 2018) or in a previously published report for Kyrgyzstan (Özkan, Mottet and Mundy, 2021).

Box 1. Regeneration of Landscapes and Livelihoods (ROLL) project

The planned ROLL project, funded by IFAD was designed in 2019 and is expected to run in Lesotho from 2021 to 2028. The project aims to facilitate the adoption and implementation of transformational practices by rural communities to regenerate 19 landscapes and create sustainable livelihoods. It aims to reach approximately 100 000 people across 16 subcatchments in five districts, corresponding to around 68 000 rural households. Landscapes are defined as "smaller areas within a subcatchment, directly associated with and used by a village or cluster of villages".

The project foresees a financial volume of USD 46 million and builds on the experiences of the Wool and Mohair Promotion Project. The primary target group consists of vulnerable rural households located in the selected catchment areas. The majority of these households keep one or two animals and mostly grow maize (IFAD, 2021a).

[1] See www.fao.org/climate-change/programmes-and-projects/detail/en/c/1401898.
[2] See www.ifad.org/es/web/latest/-/news/ifad-announces-second-phase-of-its-flagship-climate-change-adaptation-fund.
[3] See www.fao.org/gleam/resources/en/.

Table 1. Emission sources covered in GLEAM-*i*

Emission source		Description
Enteric fermentation (CH_4)		CH_4 emissions caused by enteric fermentation
Manure management (CH_4)		CH_4 emissions caused by manure management
Manure management (N_2O)		N_2O emissions arising from manure storage and management
Direct energy use of production facilities (CO_2)		CO_2 emissions arising from on-farm energy use, e.g. for lighting, ventilation, washing, cooling, heating and milking
Indirect energy use from capital goods (CO_2)		CO_2 emissions arising from energy use during the construction of machinery, tools and equipment or buildings, e.g. animal housing, forage and manure storage
Feed production and processing (CO_2)	Field operations	CO_2 emissions arising from the use of fossil fuels during field operations
	Fertilizer production	CO_2 emissions arising from the manufacture and transport of synthetic nitrogenous, phosphate and potash fertilizers
	Pesticide production	CO_2 emissions arising from the manufacture, transport and application of pesticides
	Processing and transport	CO_2 generated during the processing of crops for feed and transport by land and/or sea
	Blending and pelleting	CO_2 arising from the blending of concentrate feed
Land-use change (LUC) to expand feed production (CO_2)	Soybean cultivation	CO_2 emissions due to LUC associated with the expansion of soybean
	Cake of palm kernel	CO_2 emissions due to LUC associated with the expansion of palm oil plantations
	Pasture expansion	CO_2 emissions due to LUC associated with the expansion of pastures
Manure, fertilizer and crop residues for feed (N_2O)	Applied and deposited manure	Direct and indirect N_2O emissions from manure deposited on the fields and used as organic fertilizer
	Fertilizer and crop residues	Direct and indirect N_2O emissions from the application of synthetic nitrogenous fertilizer and the decomposition of crop residues
Rice as feed (CH_4)	Rice production	CH_4 emissions arising from the cultivation of rice used as feed (not relevant for this analysis)

Notes: CH_4: methane; N_2O: nitrous oxide; CO_2: carbon dioxide.
Source: **FAO**. 2018. *Global Livestock Environmental Assessment Model. Model Description. Version 2.0.* Rome. www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM_2.0_Model_description.pdf

Approach

Data collection and validation

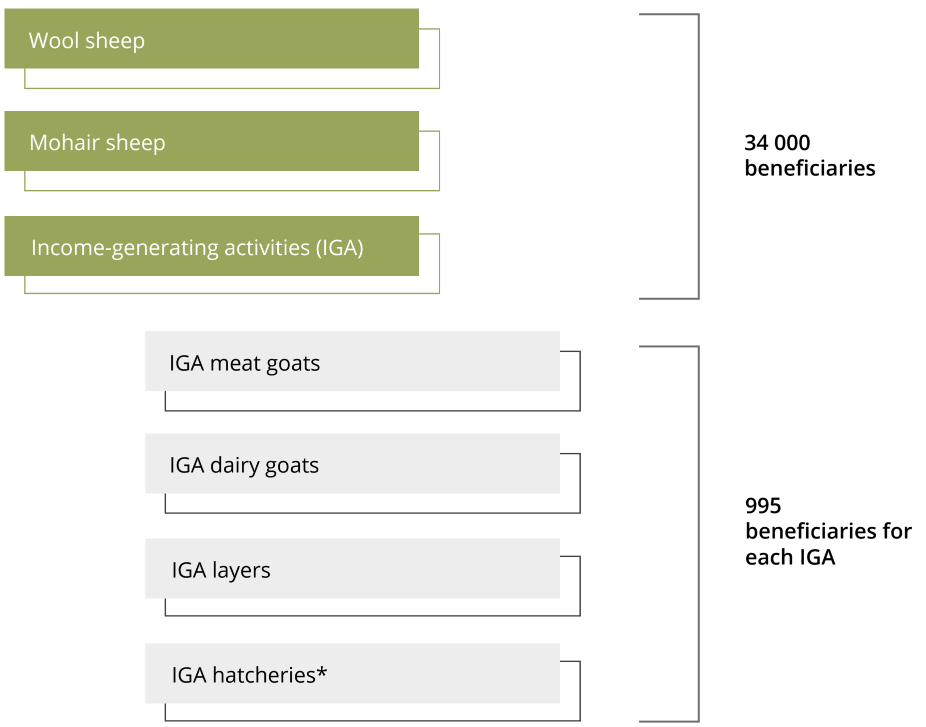
Two virtual workshops were organized on 4 May 2021 and 11 May 2021 to introduce the GLEAM-*i* tool to the relevant stakeholders, validate the default data and discuss the production systems. A number of follow-up exchanges were organized with the experts to finalize the data needs and assumptions. The project design report and the economic rate of return (ERR) master Excel documents were consulted to obtain the animal numbers.

Production systems

The ROLL project will target 68 000 rural households, 10 percent of which will have livestock only (6 800 households), with 40 percent keeping livestock and performing other agricultural activities (27 200 households) (IFAD, 2021b). Households keep one or two animals such as sheep or goats. The production systems analysed have been divided into the following subgroups for easy reference (Figure 1).

Since most of the ration consists of grazed grass, the production system selected for sheep and goats is grassland. The input parameters and assumptions for specific scenarios were inputted into the online version of GLEAM-*i*. Wool and mohair production are not primary production orientations in GLEAM-*i*, so emissions related to wool, meat and milk were simply allocated.

Figure 1. Production systems and number of households captured in the project



Notes: The green-shaded areas refer to the main systems. The species captured under the income-generating activities (IGAs) are listed in the four grey boxes.

* These are often referred to in the project documents as "incubator chicks". For the sake of clarity, "hatcheries" is used instead throughout this document. Hatcheries are systems in which one-day-old chicks are produced for broiler production. The assessment included life-cycle emissions of broiler chickens, some of which come from direct energy use and include energy used for heating, cleaning and ventilation.

Source: **IFAD**. 2021b. *ROLL ERR Analysis*.

Scenarios

Three scenarios were developed.

Baseline: This scenario represents 2022, the year that the ROLL project is expected to begin.

With project (WP): This scenario represents a situation where improvements are made to herd structure, feeding and manure management as part of the project and over the capitalization phase of 20 years. As the project aims to implement a number of measures, the WP scenario thus represents the effects of a package of measures, including selective breeding, artificial insemination, pasture restoration, improved availability and quality of fodder supply, improved animal health through vaccination, treatment for internal and external parasites and good animal husbandry.

Without project (WOP): This is the business-as-usual scenario, without any improvements being made to herd, feed or manure at the end of the capitalization phase. Comparing the WP and WOP scenarios reveals the expected impact of the project on GHG emissions. The results are presented on an annual basis.

Assumptions

Animal numbers: The animal numbers taken from FAOSTAT (FAO, 2022a) were used to calculate a percentage change in animal numbers by 2042 (WP) in comparison to 2022. According to these calculations, sheep and goat numbers may grow by 30 percent and 5 percent, respectively, by 2042, in comparison to 2022. The 52 percent increase in the country's chicken stocks is assumed to apply to layers (projection based on FAOSTAT data). The expected growth by 2042 is the result of annual increases in animal numbers by 1.6 percent, 0.3 percent and 2.8 percent for sheep, goats and chickens, respectively. For broilers, project-specific information was available and used. Nonetheless, it is assumed that half of the eggs produced would go to broiler production systems with the other half sold for human consumption to reflect the incubator capacity in the design models (assumption based on information from the project document). However, new incubators may be bought during the course of the project, therefore making it possible to produce a greater number of one-day-old chicks for broiler production. Again, these animal numbers may not be reached, but should be considered as indicative of potential future figures.

The number of animals in a WOP scenario was assumed to be the same as in a WP scenario. A male-to-female ratio of 1:8 was used for sheep and goats. This ratio was changed to 1:25 in the WP scenario, reflecting the implementation of artificial insemination. It is also important to note that even though the number of adult males is reduced, these males would still be born into the system every year and would be kept for meat, not for replacement. The model uses the following equation to calculate the new meat males each year:

Meat males entering the system = lambs and kids entering the system / 2 – replacement males entering the system.

While the number of lambs and kids entering the system is based only on the number of females, the number of replacement males entering the system is based on the number of males. Therefore, if the number of replacement adult males is reduced (with the number of lambs and kids entering the system remaining constant in the equation), more meat males will be produced (thus more meat and protein).

The numbers of adult males and females are not based on the herd composition provided in the project documents due to the information being either unavailable or unclear. To calculate the number of males, the male-to-female ratios provided in this section are used. The number of adult females is calculated based on the herd size using GLEAM-*i*. In the tool, the number of females is increased or decreased until the point at which the total number of animals in the herd in terms of raw results matches the projected figures (limit to second decimal number). The number of animals covered by the project therefore equates to the animal numbers obtained from the raw results. Table 2 presents the animal numbers captured in this part of the assessment (numbers highlighted in yellow reflect the herd sizes used in the assessment).

Table 2. Calculation of animal numbers[a]

	Baseline (2022)	Reference	WP (2042)	WOP (2042)
Wool sheep and goats (non-IGA)				
Number of households with livestock	6 800	ROLL ERR master beneficiaries (10% of 68 000)	6 800	6 800
Number of households with livestock and agriculture (mixed)	27 200	ROLL ERR master beneficiaries (40% of 68 000)	27 200	27 200
Number of households with IGA	5 525	ROLL ERR master beneficiaries	5 525	5 525
Number of households with IGA adjusted	4 973	10% taken out for beekeepers and brickmakers	4 973	4 973
Number of beneficiaries per IGA	995	4 973 / 5 (there are five IGAs)	995	995
Number of sheep or goats per household	1.5	ROLL project design report: one to two livestock animals	-	-
Number of sheep and goats	51 000	34 000 × 1.5	-	-
Ratio of sheep in total sheep and goats	73%[b]	Government of Lesotho (2018)	-	-
Ratio of goats in total sheep and goats	27%	Government of Lesotho (2018)	-	-
Number of sheep (herd size)	37 362	73% of 51 000 (baseline) + 30.2% of 37 362 (WP and WOP)	48 648[c]	48 648
Number of goats (herd size)	13 638	27% of 51 000 (baseline) + 5.1% of 13 638 (WP and WOP)	14 337[d]	14 337
Number of adult female sheep	15 500	Number adjusted in GLEAM-*i* to reach the herd size	19 000	20 000
Number of adult male sheep	1 938	Based on a 1:8 (WOP and baseline) or 1:25 (WP) male-to-female ratio	760	2 500
Herd size GLEAM-*i* calculation (wool sheep, non-IGA)	37 637		48 689	48 563
Number of adult female goats	6 000	Same as wool sheep	6 300	6 400
Number of adult male goats	750	Same as wool sheep	252	800
Herd size GLEAM-*i* calculation (mohair goats, non-IGA)	13 566		14 411	14 470
Meat goats (IGA)				

(Cont.)

[a] Parameters used in the model are highlighted in green.
[b] Assumed that the same rate applies to sheep and goats bred for meat and wool/mohair in the project.
[c] Assumed a growth rate of 30.2 percent in line with the projections.
[d] Assumed a growth rate of 5.1 percent in line with the projections.

Number of meat goats IGA	1 492	995 ×1.5 (baseline) + 5.1% of 1 492 (WP and WOP)	1 568[e]	1 568
Number of adult female goats (IGA)	610	Same as wool sheep	640	650
Number of adult male goats (IGA)	76	Same as wool sheep	26	81
Herd size GLEAM-*i* calculation (meat goats, IGA)	1 482		1 570	1 580
Dairy goats (IGA)				
Number of dairy goats (IGA)	1 492	995 × 1.5 (baseline) + 5.1% of 1 492 (WP and WOP)	1 568[f]	1 568
Number of adult female goats (IGA)	730	Same as wool sheep	760	770
Number of adult male goats (IGA)	91	Same as wool sheep	30	96
Herd size GLEAM-*i* calculation (dairy goats, IGA)	1479		1522	1560
Layers (IGA)				
Number of layers per beneficiary	8	Average number of layers (personal communication Abisi Alotsi)	-	-
Number of layers in the project (herd size)	7 956	995 × number of layers per beneficiary (× 2.14 WP and WOP)	12 112[g]	12 112
Number of females	69	Based on a male-to-female ratio of 1:10	108	108
Number of males	6.9	Based on a male-to-female ratio of 1:10	10.8	10.8
Herd size GLEAM-*i* calculation	7 936		12 342	12 422
Hatcheries (i.e. broilers) (IGA)*				
Number of chicks per beneficiary	1 224[h]	Average number of one-day-old chicks	2 592[i]	2 592
Number of chicks in the project (herd size)	608 634[j]	995 × number of chicks per beneficiary (× 2.12 WP and WOP)		
Number of females		Based on a male-to-female ratio of 1:10	58 750	63 650
Number of males	3 005	Based on a male-to-female ratio of 1:10	5 875	6 365
Herd size GLEAM-*i* calculation	**608 414**		**1 288 640**	**1 288 704**

Notes:
* Hatcheries produce one-day-old chicks which are sent to broiler production systems and thus continue to live and produce GHG emissions. This study therefore calculated the life-cycle emissions of the chicks produced until they have left the farm (up to the farm gate) as broiler chickens. The emissions from hatcheries were calculated separately using the ratio of emissions associated with hatcheries, broiler production and slaughterhouses in a Danish study (Nielsen, Jørgensen and Bahrndorff, 2011), and discussed as part of the result outputs.
[e] Assumed a growth rate of 5.1 percent in line with the projections.
[f] Assumed a growth rate of 5.1 percent in line with the projections.
[g] A growth rate of 52.2 percent has been assumed following the projections.
[h] Based on 10 chickens producing 170 eggs = 1 700 eggs of which 80 percent are hatched of which 10 percent die.
[i] Based on 20 chickens producing 180 eggs = 3 600 eggs of which 80 percent are hatched of which 10 percent die.
[j] Calculated from 1 224 × 995 (baseline) or 2 592 × 995 (WP/WOP) divided by 2 to allocate half of the eggs for human consumption and to reflect the incubator capacity.
Sources: Authors' own elaboration based on stakeholder consultations; **IFAD.** 2021b. *ROLL ERR Analysis;* **Government of Lesotho**. 2018a, 2018b.

Productivity and herd structure: In the scenario for small ruminants, the mortality rate and replacement rate are reduced by 5 percent while live weights are increased by 5 percent. Age at first parturition is reduced by 10 percent in the WP scenario compared with the baseline. The fertility rate (also for poultry for the parameter average share of eggs that successfully hatch a pullet) is increased by 3 percent. The mortality rate (18 percent) for adult goats is lower than the replacement rate (20 percent). This is because a greater mortality rate of adult females than the replacements leads to no meat production from the adult female cohort. However, these animals are still counted in the herd size, resulting in high absolute emissions and a high emission intensity (plus a low carcass weight per animal). For the mortality rates of young kids, a ratio of 31 percent is used (Ng'ambi *et al*., 2006), which contributes to a higher level of meat production from young animals. The high mortality rate of lambs is confirmed by the literature (Mpiti-Shakhane *et al*., 2002). Milk production of dairy goats is also assumed to increase by 10 percent as a result of improvements in feeding (e.g. establishing a forage production unit, concentrate feed and supplements), breeding and veterinary services, which are likely to increase the amount of milk produced during the capitalization phase of the project. In poultry, the death rate is reduced by 5 percent (except for young broilers) and the age at first parturition is reduced by 10 percent. Feed and manure: Crop residues and silage from maize are added to the diet of small ruminants, while crop residues from wheat are removed and the share of fresh grass is reduced. In poultry, by-products from cottonseed (61.4 g N/kg DM)[4] are added to replace a share of the by-products from soy (76.6 g N/kg DM). Manure is shown as a revenue item in the IGA. However, no particular intervention is mentioned for manure management systems. For manure, the share of daily spread (small ruminants and broilers) and solid storage (small ruminants and layers) is increased while the share of manure deposited on pastures (small ruminants) and pit storage (layers) is reduced (Table 3 and Table 4).

[4] g N/kg DM: grams of nitrogen per kilogram of dry matter.

Table 3. Herd, feed and manure parameters of small ruminants[a]

			Non-IGA		IGA	
Parameters	**Unit**	**Description**	**Wool sheep**	**Mohair goats**	**Meat goats**	**Dairy goats**
Herd						
Age at first parturition	Months	Average age at which adult females have their first parturition, whether it is successful or not	23 21	24 21.6	24 21.6	15 13.5
Death rate of adult animals	%	Annual average percentage of non-intended deaths of animals (males and females) after reaching maturity	15 14.25	18 17.1	18 17.1	18 17.1
Death rate of young animals	%	Annual average percentage of non-intended deaths of female animals before reaching maturity	47 44.65	31 29.45	31 29.45	31 29.45
Fertility rate of adult females	%	Percentage of lambing/kidding adult females over the total amount of adult females. This includes offspring that are born but die before reaching maturity	85 87.55	70 72.1	70 72.1	70 72.1
Litter size	Number	Average number of lambs or kids born in each parturition, including those that die before reaching maturity	1 1.2	1 1.2	1.2 1.4	1.2 1.4
Live weight of adult females	kg	Average live weight of adult females once they reach maturity	42 44.1	40 42	40 42	48 50.4
Live weight of adult males	kg	Average live weight of adult males once they reach maturity	65 68.25	42 44.1	42 44.1	70 73.5
Live weight of meat females at slaughter	kg	Average live weight at slaughter of adult females culled for meat	42 44.1	40 42	40 42	48 50.4
Live weight of meat males at slaughter	kg	Average live weight at slaughter of adult males culled for meat	65 68.25	42 44.1	42 44.1	70 73.5
Milk fat	%	Average total fat content of milk	-	-	-	3.64 Unchanged
Milk protein	%	Average total protein content of milk	-	-	-	3.51 Unchanged
Milk yield	kg/year	Annual average milk yield per milking cow	-	-	-	475 522.5
Parturition interval	Days	Average interval between two parturitions	365 Unchanged	365 Unchanged	365 Unchanged	365 Unchanged

[a] Project targets are in green.

(Cont.)

Replacement rate of adult females	%	Annual average rate of reproductive adult female replacement	20 19	20 19	20 19	20 19
Weight at birth	kg	Average live weight of offspring at birth	2.8 2.94	1.3 1.37	1.3 1.37	1.8 1.89
Feed						
Crop residues from maize	%	Fibrous residual plant material such as straw, brans, leaves, etc. from maize (*Zea mays*) cultivation	5 10	5 10	5 10	5 10
Crop residues from wheat	%	Fibrous residual plant material such as straw, brans, leaves, etc. from wheat (*Triticum spp.*) cultivation	5 0	5 0	5 0	5 0
Fresh grass	%	Any type of natural or cultivated fresh grass that is grazed by or fed to animals	70 60	70 60	70 60	70 60
Hay or silage from alfalfa	%	Hay or silage from alfalfa (*Medicago sativa*)	15 Unchanged	15 Unchanged	15 Unchanged	15 Unchanged
Maize	%	*Zea mays*	5 Unchanged	5 Unchanged	5 Unchanged	5 Unchanged
Silage from the whole maize plant	%	Silage from the whole maize (*Zea mays*) plant	0 10	0 10	0 10	0 10
Manure						
Daily spread	%	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion	0 10	0 10	0 10	0 10
Pasture/range/paddock	%	The manure from pasture and range-grazing animals is allowed to lie as deposited and is not managed	70 50	70 50	70 50	70 50
Solid storage	%	The storage of manure, typically for a period of several months, in unconfined piles or stacks	30 40	30 40	30 40	30 40

Source: Authors' own elaboration based on stakeholder consultations conducted to validate GLEAM-*i* default parameters.

Table 4. Herd, feed and manure parameters of poultry[a]

Parameters	Unit	Description	Layers	Broilers
Herd				
Age at first parturition (parents)	Weeks	Average age at which adult females have their first parturition, whether it is successful or not	16 14.4	16 14.4
Annual average number of eggs laid	Number/year	Number of eggs laid per laying hen per year	180 Unchanged	170 180
Average duration of laying cycle	Weeks	Average length of the (first, if more than one) laying period of egg-producing hens	60 Unchanged	27 Unchanged
Average share of eggs that successfully hatch a pullet	Ratio	Hatchability ratio	0.8 0.82	0.8 0.82
Average weight of whole eggs	g	Average weight of a whole egg	45 Unchanged	45 Unchanged
Death rate during laying period	%	Annual average percentage of non-intended deaths of animals (males and females) after reaching maturity, i.e. pullets after 16 weeks	5 4.75	10 9.5
Death rate of adult broilers	%	Annual average percentage of deaths of adult broilers	-	7 6.65
Death rate of young females	%	Annual average percentage of non-intended deaths of female animals before reaching maturity, i.e. pullets before 16 weeks	4 3.8	4 Unchanged
Laying parent hen final weight	kg	Weight of a laying parent at the end of the laying period	1.5 Unchanged	1.7 Unchanged
Laying parent hen initial weight	kg	Weight of a laying parent at the start of laying period	1.2 Unchanged	1.3 Unchanged
Live weight at slaughter	kg	Weight of a laying parent at slaughter	-	1.5 Unchanged
Weight at birth	kg	Average live weight of offspring at birth	0.04 Unchanged	0.05 Unchanged
Feed				
By-products from oil production	%	By-product (cakes, meals) from oil production other than soy, cottonseed or palm oil	7 Unchanged	-
By-products from cottonseed	%	By-product from cottonseed (*Gossypium spp.*) oil production, commonly referred to as "cottonseed cakes"	0 8.5	0 13.5
By-products from soy	%	By-product from soy (*Glycine max*) oil production, commonly referred to as "soy cakes" or "soybean meal"	17 8.5	27 13.5

[a] Project targets are in green.

(Cont.)

Grains from maize	%	Grains from maize *(Zea mays)*	59 Unchanged	65 Unchanged
Grains from wheat	%	Grains from wheat (*Triticum aestivum*)	9 Unchanged	6 Unchanged
Limestone	%	Used as a source of calcium and given to laying hens to promote the formation of the eggshell	7 Unchanged	1 Unchanged
Synthetic additives	%	Synthetic additives such as amino acids or minerals	1 Unchanged	1 Unchanged
Manure				
Daily spread	%	Manure is routinely removed from a confinement facility and is applied to cropland or pasture within 24 hours of excretion	-	0 10
Pit storage	%	Collection and storage of manure, usually with little or no added water, typically under a slatted floor in an enclosed animal confinement facility, normally for periods of less than one year	90 50	-
Poultry manure with litter	%	Similar to deep bedding for cattle and swine, except usually not combined with a dry lot or pasture	10 20	100 90
Solid storage	%	The storage of manure, typically for a period of several months, in unconfined piles or stacks	0 30	-

Source: Authors' own elaboration based on stakeholder consultations conducted to validate the GLEAM-*i* default parameters.

Allocation of emissions

Livestock systems produce more than one type of product or service (edible or non-edible). In the case of wool sheep and mohair goats captured in this assessment, these animals not only produce fibre (primary purpose of production), but also meat when they are slaughtered. Therefore, the emissions associated with raising these animals need to be allocated to both products. If physical relationships cannot be established for different products and services, as in the case of wool/mohair and meat, the allocation should reflect the fundamental relationship. This is called the economic allocation and is obtained by allocating emissions to each product based on their individual economic value compared with the combined economic value (Opio *et al*., 2013). The fractions of emissions allocated to wool and fibre are presented in detail in the respective section. To allocate emissions, the number of replacement females is first calculated and subtracted from the total number of animals in the herd, since they are assumed not to contribute to fibre production (Table 5). The calculation of the number of replacement females is performed according to the formulae provided in this section, in line with the GLEAM model description (FAO, 2018).

$$((RFin + RF1) / 2) + (((RF1 + AFin) / 2) \times (AFC - 1))$$

Where: RFin = replacement females entering the herd; RF1 = replacement females at the end of first year; AFin = adult females entering the herd; AFC = age at first parturition.

$$RFin = ((AF \times (RRF / 100)) / FRRF) / ((1 - (DR1 / 100)) * (1 - (DR2 / 100))(AFC - 1))$$

Where: RRF = replacement rate of females; FRRF = fertility rate of replacement females (assumed to be 95 percent); DR1 = death rate of young animals; DR2 = death rate of adult animals.

$$RF1 = RFin \times (1 - (DR1 / 100))$$

$$AFin = AF \times (RRF / 100)$$

Table 5. Number of replacement females in each scenario for wool sheep and mohair goats

	Wool sheep			Mohair goats		
	Baseline	WP	WOP	Baseline	WP	WOP
Replacement rate females (RRF)	20	19	20	20	19	20
Adult females (AF)	15 500	19 000	20 000	6 000	6 300	6 400
Adult females entering the herd (AFin)	3 100	3 610	4 000	1 200	1 197	1 280
Death rate of young animals (DR1)	47	44.7	47	31	29.5	31
Death rate of adult animals (DR2)	15	14.3	15	18	17.1	18
Age at first parturition (AFC)	1.9	1.7	1.9	2	1.8	2
Replacement females entering the herd (RFin)	7 146	7 675	9 221	2 233	2 075	2 381
Replacement females first year (RF1)	3 787	4 248	4 887	1 540	1 464	1 643
Replacement females (RF)	8 623	8 810	11 127	3 257	2 834	3 474

Source: Authors' own calculation based on GLEAM model description in FAO (2018)

The procedure used to calculate the fraction of emissions allocated to fibre and meat for wool sheep and mohair goats can be found in Table 6.

Table 6. Allocation of emissions*

	Unit	Sheep			Goats		
		Baseline	WP	WOP	Baseline	WP	WOP
Meat							
Average live weight	kg/head	53.5	56.2	53.5	41.0	43.1	41
Carcass fraction	% of live weight	50					
Carcass weight (CW)	kg/head	26.8	28.1	26.8	20.5	21.5	20.5
Cost of a live animal	LSL/head[a]	650			800		
Meat price	LSL/kg CW	24	23	24	39	37	39
Total system CW	kg	182 453	350 604	235 429	23 914	42 984	25 509
Meat value	LSL	4 433 440	8 113 675	5 720 705	933 248	1 597 563	995 464
Wool/mohair (fibre)							
Wool/mohair production	kg/head/year	2.6	3.0	2.6	0.75	1.0	0.75
Number of animals in the system	heads	37 637	48 689	48 563	13 566	14 411	14 470
Replacement females in the system[b]	heads	8 623	8 810	11 127	3 257	2 834	3 474
Number of animals in the system minus replacement females[c]	heads	29 013	39 879	37 436	10 309	11 577	10 996
Total amount of wool/ mohair in the system	kg/year	75 434	119 637	97 333	7 732	11 577	8 247
Cost of a B-class wool	LSL/kg	60			-	-	-
Wool value	LSL	4 526 061	7 178 213	5 839 995	-	-	-
Cost of a green mohair	LSL/kg	-	-	-	85		
Mohair value	LSL	-	-	-	657 191	984 051	701 004
Total economic value (meat + wool/mohair)	LSL	8 959 501	15 291 888	11 560 701	1 590 439	2 581 613	1 696 468
Fraction wool	%	0.51	0.47	0.51			
Fraction sheep meat	%	0.49	0.53	0.49			
Fraction mohair	%				0.41	0.38	0.41
Fraction goat meat	%				0.59	0.62	0.59

Notes:

* According to these calculations, 47 percent and 51 percent of emissions are allocated to wool, and 38 percent and 41 percent of emissions are allocated to mohair in the WP and WOP scenarios, respectively, while the rest is allocated to meat production. To calculate the emission intensity for proteins, the emissions from milk and meat are divided by the amount of protein in meat and milk. The emission intensity for wool (kg CO_2e/kg fibre) is calculated by dividing the emissions allocated to fibre by the amount of fibre production in kilograms. The emissions associated with milk and meat in the case of dairy goats are calculated based on the raw results of GLEAM-*i* on emissions originating from milk (83 percent and 87 percent, WP and WOP, respectively) and meat (17 percent and 13 percent, WP and WOP, respectively).

[a] LSL is the ISO currency code for the Lesotho loti, the currency of Lesotho.

[b] See Table 5 for calculating the number of replacement females.

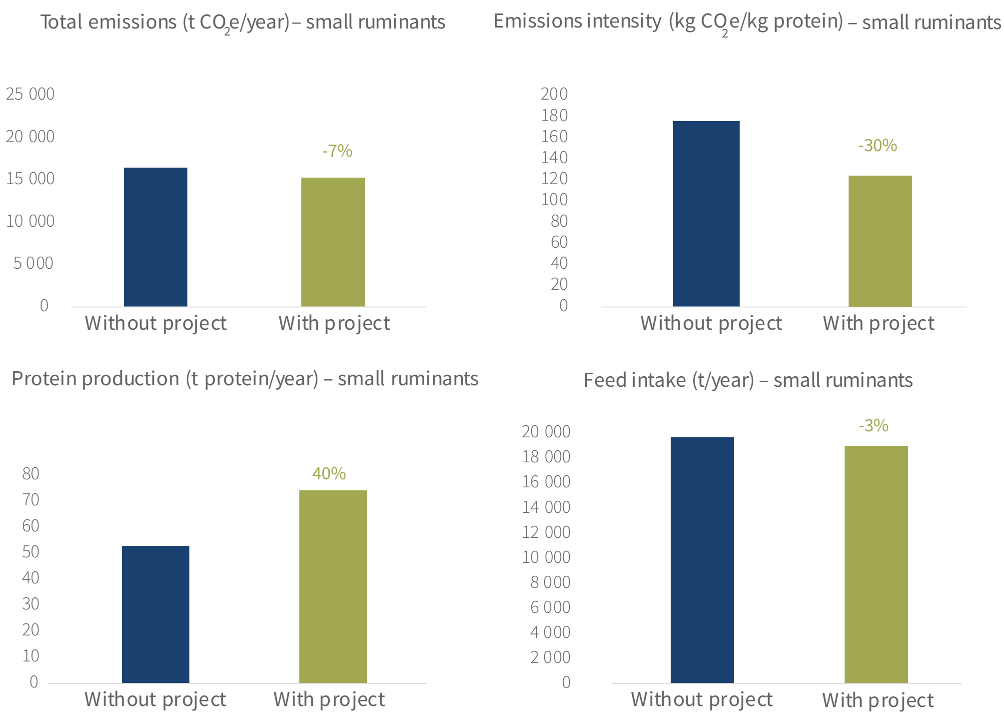
[c] Number of replacement animals was deducted because they were assumed not to contribute to wool production (GLEAM-*i* assumption).

Source: Authors' own elaboration calculation based on GLEAM model description in FAO (2018).

Results and discussion

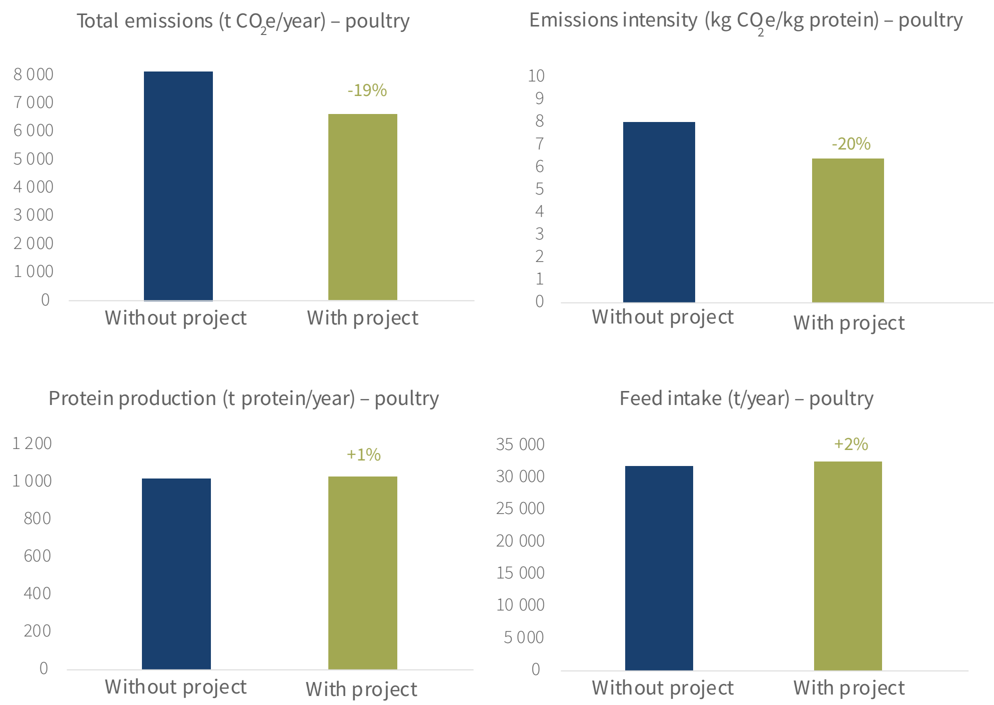
The results show that the total emissions (aggregated across all systems) are 11 percent lower in the WP scenario (21 916 t CO_2e/year) compared with the WOP scenario (24 589 600 t CO_2e/year). Emissions from across all products are reduced, with the reduction being most pronounced in emissions associated with eggs (layers) by approximately 27 percent. When categorized by small ruminants and poultry, total emissions decrease by 7 percent (from 16 458 kg to 15 334 kg CO_2e/year) and 19 percent (from 8 132 kg to 6 582 kg CO_2e/year), respectively. Protein production in small ruminants increases from 53 tonnes of protein per year in the WOP scenario to 74 tonnes of protein per year in the WP scenario, representing a 40 percent increase. In poultry, protein production increases from 1 018 tonnes of protein per year (WOP) to 1 028 tonnes of protein per year (WP). The emission intensity can be expressed in different units. When expressed per kilogram of protein, it decreases by 30 percent in small ruminants and by 20 percent in poultry. Fibre production increases by 24 percent (Figure 2 and Figure 3).

Figure 2. Total emissions, emission intensity, protein production and feed intake in small ruminants



Source: Authors' own elaboration based on GLEAM-*i* calculations.

Figure 3. Total emissions, emission intensity, protein production and feed intake in poultry



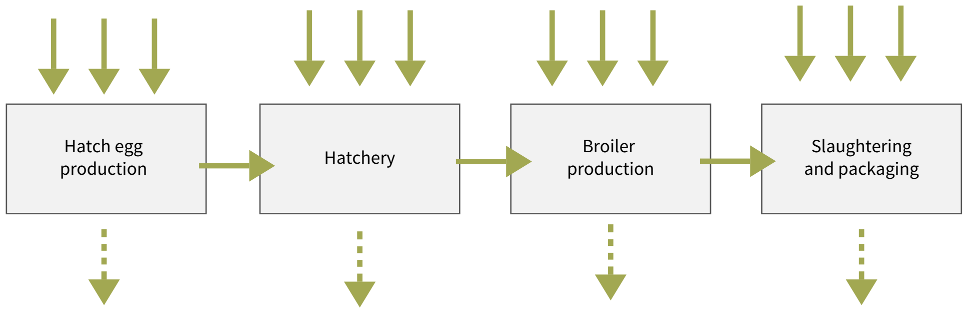
Source: Authors' own elaboration based on GLEAM-*i* calculations.

Emissions associated with hatcheries

The emissions reported under broiler systems include all life-cycle emissions. The flow of processes in a broiler production system includes hatching-egg production, hatchery, broiler production, slaughtering and packaging. Hatching-egg production may be responsible for 13.5 percent of the total emissions from the system, while broiler production accounts for 76.4 percent of emissions. Slaughterhouse emissions make up 10.1 percent of the total (Nielsen, Jørgensen and Bahrndorff, 2011) (Figure 4).

CO_2 emissions associated with direct energy use on the farm include ventilation, heating and cleaning. While some of these emissions originate from hatcheries, the model results do not differentiate the proportion originating from hatcheries only. Nevertheless, the CO_2 emissions from direct energy use in relation to broilers do not change greatly in the WP scenario (2 310 t CO_2e/year) compared with the WOP scenario (2 285 t CO_2e/year). Had the ratio from Nielsen, Jørgensen and Bahrndorff (2011) been used (17.7 percent of emissions coming from broiler production: 13.5 divided by 76.4), emissions from hatcheries only would have been 1 148 t CO_2e/year and 1 416 t CO_2e/year in the WP and WOP scenarios, respectively. However, please note that this is a simplification and the ratio using Danish data may not be representative of Lesotho.

Figure 4. Flow in broiler production



Notes: The boxes refer to processes, while the arrows illustrate inputs from external sources and transport from one process to another. By-products (e.g. manure and slaughter waste) are indicated by dashed arrows.
Source: **Nielsen, N.I., Jørgensen, M. & Bahrndorff, S**. 2011. *Greenhouse Gas Emission from the Danish Broiler Production Estimated via LCA Methodology.* Knowledge Centre for Agriculture. https://lca-net.com/wp-content/uploads/110628_vfc_engelsk_vfl_layout_web.pdf

Reflections and recommendations

Technical entry points

A combination of measures was implemented at the herd, feed and manure levels in this study. Some practices may be implemented by the project individually (i.e. not part of a package) and only for a selected number of beneficiaries, leading to different results than those reported here. The magnitude of emission reductions cannot be gauged for individual practices or the number of beneficiaries because the project has not been implemented yet. Nevertheless, the moderate changes made to the parameters should represent a potential future, rather than a "concrete" future.

Herd level

i. Breeding animals at a slightly earlier age (e.g. a 10 percent reduction from the baseline) leads to a reduction in the number of young animals needed to replace the adult females. A higher number of adult males become available for selling and the number of meat animals is reduced, leading to a smaller herd size.

ii. Increasing the fertility rate slightly (e.g. by 3 percent) leads to an increased number of meat animals, lambing/kidding adult females and living lambs/kids. As a result, the herd size grows. This can also apply to hatchability for poultry.

iii. Reducing the death rate of animals means that more meat animals become available to produce meat. A lower death rate among adult females leads to fewer replacements and the herd size increases overall.

iv. Reducing replacement rates of adult females in small ruminants by 5 percent leads to fewer adult females leaving the farm as well as fewer new animals from calves, leading to a reduction in herd size.

v. Increasing the litter size from 1.0 to 1.2 for fibre animals, and from 1.2 to 1.4 for meat and dairy goats used for IGAs, results in an increase in the size of the herd. For example, in a herd with 100 adult females giving birth to 120 kids (for IGAs with a litter size of 1.2), 140 kids would be born in a WP scenario with a litter size of 1.4 instead.

In Lesotho, the project should focus on improving animal health and reproductivity, which would lead to a greater amount of protein production (small ruminants) without increasing the number of animals. Improved accessibility and the quality of animal health services, vaccination, treatment of external and internal parasites, as well as a selective genetic improvement and reproduction programme that does not only include exotic breeds, but also the traits of local breeds (able to withstand extreme weather conditions) are crucial for reducing mortality rates and increasing milk, meat and fibre production. Protecting animal welfare and improving farming productivity are therefore closely linked, as healthy animals are naturally more efficient at utilizing natural resources. The lower carbon footprint resulting from these practices would eventually benefit the whole agricultural ecosystem, strengthening value chains while enhancing rural livelihoods.

Feed level

i. Increasing the share of maize either from crop residues (by replacing it with those from wheat) or as silage while reducing the share of fresh grass can lead to a reduction in overall emissions from small ruminants. Reducing the share of fresh grass can also help diminish the grazing pressure on pastures. Feeding maize to small ruminants in sub-Saharan Africa is not an unrealistic concept. However, if the rise in temperature exceeds the 2 °C target, increased daytime temperatures of above 30 °C are likely to reduce yields (Mulenga, Wineman and Sitko, 2017). Climate-proofing maize production by developing and using varieties that can withstand water stress and mature early will prove important, as will planting earlier in the year and raising awareness of the impacts of climate change on agriculture (Omoyo, Wakhungu and Oteng'i, 2015).

ii. For poultry, reducing the reliance on soy remains a priority because halving the amount of soy and replacing it with cottonseed meal can help reduce emissions from feed.

iii. When selecting the changes in the percentage of individual feed ingredients, the energy and protein content of the feed ingredients (i.e. energy-rich or protein-rich), in addition to the source of the feed (i.e. imported soy versus locally grown feed) should be considered. In general, grains contain high amounts of energy whereas by-products are rich in protein. Forages, depending on how they have been processed, may contain high amounts of energy and low levels of fibre (e.g. fresh grass) or low amounts of energy and high levels of fibre (e.g. hay).

The project can benefit from exploring opportunities to improve the availability of maize for small ruminants and find alternative sources of protein for poultry to reduce reliance on imported soy. Maize yields will be greatly affected by increases in daytime temperatures. Climate-proofing maize production by developing maize varieties that can withstand water stress and mature early, as well as adjusting crop calendars to allow for early planting can also be considered. Increasing awareness of climate change and its impacts on agriculture will also be crucial to developing tailored adaptation strategies. In this context, pasture resting, rotational grazing on seasonal pastures or designated paddocks, protecting water resources and managing herd growth to align stocking rate with the changing biomass availability, in addition to implementing better-quality fodder production would be the recommended climate-adaptation practices.

Manure level

i. Reducing the share of manure deposited on pastures from 70 percent to 50 percent, increasing the ratio of manure stored in solid form from 30 percent to 40 percent and allocating a 10 percent share to be spread daily would reduce emissions from manure in small ruminants.

ii. For layers, more manure is stored in solid storage (30 percent); for broilers, a 10 percent share is considered to be spread daily, while the rest is stored with litter. Storing manure from layers in solid form could be investigated further, as this technique is used in Latin America, North America, where 70 percent of manure is stored in solid form, and in South Asia, where 100 percent of manure from layers is stored in solid form (MacLeod *et al.*, 2013).

iii. CH_4 emissions may be higher when manure is stored in liquid form, while N_2O emissions may be higher in dry-lot or solid systems (FAO, 2022b). However, emissions from manure are usually low in most systems where manure is stored in solid form.

The project should recognize that manure is a rich source of nutrients and organic matter that is not only key for soil health and fertility but can contribute to a more circular and sustainable bioeconomy. It can be worthwhile to consider investing in infrastructure for manure management systems to avoid nutrient loss. Exploring practical implementation to spread manure daily and store it in solid form can be beneficial. Biogas plants can be an option, but the scale of such plants should be reasonable, as large-scale implementations may require more animals to be stalled.

Animal numbers

- The potential growth in animal numbers is reflected by the trends reported by FAOSTAT (FAO, 2022a) from 2005 to 2019, which are used to project animal numbers in 2022 and 2042. However, the trend for systems with different orientations, such as for meat, milk, wool and mohair, may be different. Future animal numbers will also depend on the policies implemented in the country. Therefore, they should be used only as an indication.
- Animal numbers are based on the number of households, meaning that if the number of households reached by the project during implementation differs from the figures reported here, the animal numbers will also change.
- The project aims to increase the number of eggs for hatcheries to 180 eggs per chicken using 20 chickens per beneficiary (3 600 chicks per beneficiary) from 170 eggs per chicken using 10 chickens per beneficiary (1 700 chicks per beneficiary). Accounting for the unhatched-eggs (20 percent of eggs laid) and mortality (10 percent of chicks produced from hatched eggs), the number of one-day-old chicks per beneficiary (2 592) could be realistic in the WP scenario. However, once multiplied by the number of beneficiaries (995) and halved to consider the hatchery capacity, the number of chicks (around 1.3 million in 2042) is much higher than the number of chickens in the country (around 420 000 chickens in 2019). This number may not be so unrealistic given that there are still 20 years remaining to observe the impact of the project.

Broilers versus hatcheries

- The project targets hatcheries and aims to increase the number of one-day-old chicks that are subsequently taken up by (intensive) broiler systems to produce meat. No information was found on the fate of one-day-old chicks nor on the efficiency levels of broiler systems in project documents. It was decided that reporting the GHG emissions only from hatcheries may be an underestimation of the emissions from broiler systems, since one-day-old chicks continue to produce GHG emissions once they enter these systems. Therefore, the results capture the life-cycle emissions of broilers, in addition to some separate estimates of emissions associated with hatcheries.

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Data availability and quality

- The project foresees the participation of all actors from a diversity of systems (e.g. large livestock owners, semi-commercial and commercial farmers) (IFAD, 2021a). Around 20 percent of the animals targeted in the project may be part of semi-intensive systems. However, the project documents report that each household keeps one to two animals which, since semi-intensive systems would have a higher number of animals, is not consistent with this figure. Furthermore, the lack of evidence on the potential number of animals in intensive systems resulted in this study focusing exclusively on extensive rural systems. Given that intensive systems function with a higher level of efficiency compared with extensive systems, relatively speaking, the actual impact on GHG emissions (if 20 percent of animals are indeed located in intensive systems) may be lower than that reported here.
- The project design report (IFAD, 2021a) refers to the provision of technical assistance to sustainable poultry and piggeries. However, no further details were found on the extent of the impact nor on the size of piggeries. As a result, piggeries were excluded from the study. Similarly, expert discussions revealed that dairy cattle may also be targeted during the project. However, given the lack of data and knowledge on the targets, dairy cattle were also excluded from the study.
- It was understood that the project would potentially target backyard chicken systems with a dual-purpose production (i.e. meat and eggs). However, no specific targets were found in the project documents in relation to the number of beneficiaries targeted in backyard systems. Therefore, no assessment was made for this type of system.

Potential input for the nationally determined contribution update

Although the contribution of Lesotho to climate change is limited, agriculture is the second-largest emitter of GHGs (35 percent) in the country, 94 percent of which emanate from livestock (World Bank and CIAT, 2018). In this context, Lesotho has ratified the Paris Agreement, and its nationally determined contribution (NDC) (Lesotho Meteorological Services, 2017) provides details on the mitigation and adaptation actions planned for various sectors, including livestock, up until 2030. The mitigation target corresponds to a combined total emission reduction of 35 percent of GHG emissions below business-as-usual.

The results reported in this study can be used to assess the impact of the project as a potential contribution to the country's revised NDC. The main technical entry points are:

i. The GWPs used to convert CH_4 and N_2O to CO_2e were 21 and 310 for CH_4 and N_2O, respectively, following the IPCC's Second Assessment Report (Houghton *et al*., 1996), whereas GWPs (34 and 298 for CH_4 and N_2O, respectively) from the IPCC's Fifth Assessment Report were used in this assessment (Myhre *et al*., 2013).

ii. The results reported in this section here indicate only the direct GHG emissions (CH_4) from enteric fermentation and CH_4 and N_2O from manure management to comply with the inventory methodologies.

Using the results from all animals and production systems, in addition to the technical entry points, the project can reduce absolute emissions by 7 percent from 10 528 t CO_2e in the WP scenario to 9 770 t CO_2e in the WOP scenario. This can be achieved while increasing total protein production by approximately 3 percent from 1 070 tonnes to 1 102 tonnes per year. The emission intensity for protein can be reduced by 7 percent with the project compared to without the project. The fact that feed intake remains unchanged can be investigated further as an adaptation strategy to reduce vulnerability. Further details on the NDC-related calculations and observations can be provided upon request.

To conclude, identifying the magnitude of change in GHG emissions as a result of certain mitigation options would require using the Tier 2 methodology of the IPCC to better capture the impact of changes in livestock management practices and animal performance. This is because the Tier 1 methodology relies on default emission factors per animal, which may not represent the country's conditions. It will be also important to use a model tailored to calculating GHG emissions from the livestock sector to account for improvements in herd, feed and manure management, as generic models may not capture the interventions that are relevant for the livestock sector in the country.

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