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Benchmarking smallholder goat enterprises and practices in central Lao PDR and farmer response to a research and development program

Luisa Olmo[A,D,*], Ammaly Phengvilaysouk[B], Alison F. Colvin[A], Phonepaseuth Phengsavanh[B], Joanne Millar[C], Thaixiong Xaikhue[A] and Stephen Walkden-Brown[B]

For full list of author affiliations and declarations see end of paper

***Correspondence to:**
Luisa Olmo
School of Environmental and Rural Science, The University of New England, Armidale, NSW 2351, Australia
Email: luisa.olmo@une.edu.au

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ABSTRACT

Context. In Lao People's Democratic Republic (Laos), goat numbers are rapidly growing and have the potential to improve rural and economic development through income generation. **Aims.** To implement a goat research and development program and benchmark and evaluate smallholder practices. **Methods.** In the first year (2020), forage growing was facilitated through formal and on-the-job monthly training. In Year 2 (2021), local staff were trained in inexpensive and locally available veterinary treatments of goats. Mineral blocks were introduced with a 50% subsidy, following a 2-month trial period. In Year 3 (2022), metal roofing material was provided to households that constructed new goat houses with elevated and slatted flooring. Annualised farmer benchmarking surveys (BMS) and monthly household surveys (MHS) monitored farmer practice change between 2020–2023 and 2021–2022 respectively. **Key results.** The BMS and the MHS confirmed significant rises in the proportion of farmers using mineral blocks between 2020 and 2023 at 303% ($P < 0.001$) and between 2021 and 2022 at 53% respectively. The BMS and MHS also reflected an increase in the proportion of farmers growing forages between 2020 and 2023 (204%) and between 2021 and 2022 (9%), a decrease in the proportion of households treating sick goats with drugs between 2020 and 2023 (47%) and between 2021 and 2022 (53%), and an increase in the proportion of farmers providing concentrate feed between 2020 and 2023 (34%) and between 2021 and 2022 (increased from 0 to 4.2%) respectively. **Conclusions.** Mineral blocks have a high potential for adoption with a trial and subsidisation period. It is recommended to increase daily grazing duration from 6–8 h to be as long as practical to reduce the impacts of late dry-season feed shortages (April–May), which coincided with a natural peak in kidding. Average goat herd size increased by three goats over the course of the project, which may reflect improved financial security as livestock are a form of asset storage. **Implications.** These trends show short-term practice change; however, further research is needed to verify whether these changes increase goat growth rate, health and kid survival.

Keywords: farmer adoption, husbandry, international agricultural development, kidding, Laos, livestock, small ruminants, Southeast Asia.

Introduction

Goats are vital to improving livelihoods and food security, most notably in developing countries. They perform various roles, including providing a readily available source of food, serving as a bank account, and facilitating ceremonial occasions (Liehr *et al.* 2024*a*). Smallholders typically integrate goats into mixed crop–livestock systems, where various livestock species and crops complement one another (Kumar *et al.* 2016; Monau *et al.* 2017; Ouchene-Khelifi *et al.* 2021). Despite having lower growth rates than sheep under favourable conditions (Van Niekerk and Casey 1988), goats possess physiological mechanisms that enable them to inhabit both humid and arid environments (Silanikove 2000). Their versatility supports communities in vulnerable regions such as Sub-Saharan Africa, southern and Southeast Asia, and the Middle East, assisting these communities to overcome poverty,

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drought, flood, and war (Lu 2023). Additionally, their ability to use inexpensive feed resources, their short gestation, and higher prolificacy than that of cattle, renders goats as a desirable option for agricultural development agendas and initiatives to secure human nutrition (IFAD 2021).

Research and development programs play a pivotal role in enhancing livestock productivity globally. In general, these programs aim to disseminate knowledge and technology to farmers and incite practice change to improve livestock efficiency and livelihoods (Ndoro *et al.* 2014; Adisa 2015). Studies in Lao People's Democratic Republic (Lao PDR or Laos) have described practical extension activities in detail and their impacts, but have focussed mainly on cattle and pigs (Millar and Connell 2010; Olmo *et al.* 2017; Olmo *et al.* 2021). These studies equipped farmers with improved forage seeds and facilitated forage plot development, which resulted in enhanced income, time savings, and improved calving rates. Although these lessons provide a foundation, evidence-based approaches to extension programs for goats in Laos remain unclear.

Laos is a country that is likely to benefit from livestock extension to enhance goat productivity. The importance of goats is rising, evidenced by goat numbers doubling from 367,000 head in 2010 to 753,860 in 2022 (FAOSTAT 2024). The increase is attributed to the growing demand from neighbouring Vietnam, which imports an estimated 90% of goats produced in Laos (Gray *et al.* 2019). With Laos having a particularly low GDP per capita of US$2054 in 2022 (World Bank 2024) and agriculture being the livelihood of 52% of households (Lao Statistics Bureau 2021), goats have been identified as an emerging export commodity, with the potential to drive rural and economic development. A scoping study of goat production in Laos concluding in 2018 identified poor nutrition, disease and inbreeding as areas requiring extension (Gray *et al.* 2019). These findings led to the co-funding of the 'Goat Production Systems and Marketing in Lao PDR and Vietnam' project (ACIAR LS/2017/034) by the Australian and Lao governments.

This paper aims to describe and evaluate an extension program to enhance smallholder goat productivity within the LS/2017/034 project entitled 'Goat production systems and marketing in Lao PDR and Vietnam', drawing on the experiences of local livestock extension professionals. Two longitudinal farmer surveys were used to characterise goat production systems, evaluate adoption, and report the strengths and limitations.

Materials and methods

Approval to conduct two surveys and implement agricultural interventions through local extension services was obtained from the University of New England Human Ethics Committee (Approval numbers HE19-218 and HE20-002). Participants were provided with information sheets that outlined the project objectives, the confidentiality of their personal information, the voluntary nature of participation, and the option to withdraw from the project without any repercussions. Verbal consent for project participation was digitally recorded.

Site selection and project design

The LS/2017/034 project was conducted in seven villages within Savannakhet province, which has the highest number of goats in Laos (MAF 2020). Seven villages were selected from three districts with active District Agriculture and Forestry Office (DAFO) extension staff. The districts included Songkhone (three villages selected), Phin (three villages selected), and Sepon (one village selected). Phin and Sepon are more mountainous, whereas Songkhone is flatter. The village selection process was based on the following criteria: (1) high abundance of goats (minimum of 80 goats), (2) at least 10% of households engaged in goat farming, and (3) willingness of farmers to participate in the project. Subsequently, 10 households were randomly selected from each village, guided by the following household criteria: (1) possession of at least five goats, (2) willingness to participate in the project, and (3) availability of labour and land to support potential management changes. In total, 70 households were recruited (30 from Songkhone district, 30 from Phin district and 10 from Sepon district). Sample size was determined on the basis of DAFOs capacity to provide consistent longitudinal extension services, ensuring alignment with sample-size calculations, assuming a 50% expected proportion (used when proportions are unknown), a 90% confidence level, and a 10% precision (Dhand and Khatkar 2014). Given the consideration of several explanatory variables and random effects, sample size calculations posed challenges.

Survey design

Two farmer surveys were designed to monitor goat management and productivity. These were the benchmarking survey (BMS) and the monthly household survey (MHS). The BMS contained up to 150 mostly closed and some open questions. The survey consisted of the following eight sections: household information (including farming and livelihood system), characteristics of the goat enterprise (goat numbers, changes to herd size and goat management system), goat raising constraints, goat enterprise decision-making, motivation/sustainability/confidence, general goat herd information (months of kidding and replacement breeding stock), and goat husbandry practices. The BMS was administered at the beginning (early 2020), middle (late 2021), and end (mid-2023) of the research project. The focus of the BMS was on goat farming systems over the past 12 months (annualised questions). In the 2021 BMS, two additional questions were included to survey participants on the impacts of COVID-19. The MHS consisted of 66 questions

and was designed to enable stock number reconciliation from monthly survey of the number of births, deaths, sales, purchases, and missing goats. This was captured alongside goat husbandry practices, farm activities, and the presence of disease syndromes. The results of stock reconciliation as well as annualised key performance indicators from the MHS will be published separately. The MHS employed skip logic to minimise the number of questions asked to the farmers only to those that were relevant on the basis of answers provided. The MHS was conducted monthly from May 2020 to October 2022 and surveyed changes occurring in the last month. In both surveys, a core set of questions was included, covering topics such as common disease syndromes, kidding, and key management practices.

To facilitate data collection, the surveys were integrated into CommCare® software (developed by Dimagi Ltd, Cambridge, MA, USA, https://dimagi.com/commcare/), which was installed on Android tablet devices to enable mobile data acquisition to a centralised server. This software minimised data-entry errors through validation tools, eliminated manual data input and reduced the amount of translation required for acquired data. All authors and the field-team received training on the use of CommCare within six months prior to the start of the survey. The survey was initially drafted in English, before being translated to the Lao language by a project team member fluent in both English and Lao and with a sound technical understanding of animal science. The survey was pretested before final corrections to the survey were made, to facilitate flow and accuracy. The finalised survey was conducted individually by project staff from either the National Agriculture and Forestry Research Institute (NAFRI), DAFO or the Provincial Agriculture and Forestry Office (PAFO). Farmers were interviewed in the Lao language on a one-on-one basis to avoid group conformity. Prices and income were recorded in the local currency, the Lao Kip. Income was averaged per survey and retrospectively converted to US$ on the basis of the median exchange rate for the respective period that the responses related to per survey and were not based on daily conversion rates. Values presented in US$ should be interpreted as approximate guides because there were substantial fluctuations in exchange rates during the study period. Open text survey responses were subsequently converted to their corresponding English option through CommCare for analysis.

Participatory extension approach

The field team in Laos, comprising two DAFO staff, two PAFO staff, and a veterinarian, was led by two NAFRI staff. Employing a range of field staff per institution was intended to reduce bias. Starting in January 2020, the field team conducted monthly visits to each farm, a practice that continued until February 2022 (Fig. 1). From March 2022 to July 2023, visits were conducted bimonthly to ease the demands on field staff and farmers. In the first year (2020), DAFO and PAFO staff received training from NAFRI in forage cultivation. Subsequently, the field team began providing monthly on-the-job training to farmers, focusing on forage establishment, management, and utilisation (Fig. 2). Each farmer was given 300–400 g of seed per forage variety, including *Brachiaria* hybrid Mulato, *Panicum maximum* cv. Simuang, *Paspalum atratum* cv. Terenos, and *Stylosanthes guianensis* cv. CIAT 184. In Year 2 (2021), the project veterinarian commenced low-cost and locally available veterinary treatment for goats, while simultaneously training farmers, and DAFO and PAFO staff in these methods. These treatments included parasiticides to treat internal and external parasites, topical antiseptics to disinfect wounds, orf-like lesions and eye infections (eye-drops), and long-acting antibiotics and vitamin injections to treat respiratory infections. During the same year, PAFO and DAFO staff also underwent training in gender awareness, which included

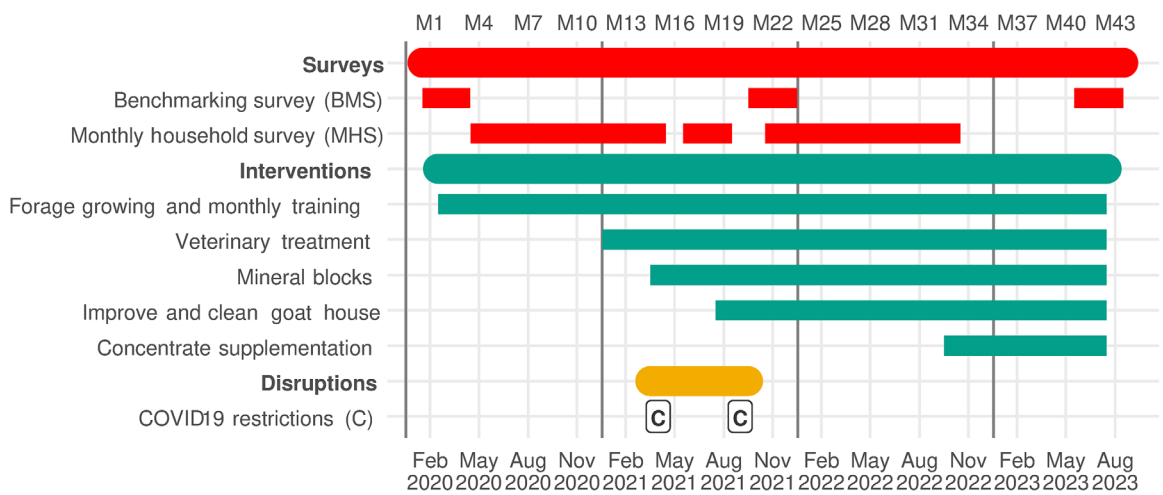

Fig. 1. Gantt chart of study activities conducted on 70 smallholder goat farms from Savannakhet, Lao PDR.

Fig. 2. Goat farmers attending forage growing training in Savannakhet, Laos, 2020.

exploring household gender roles in relation to goat husbandry. In April 2021, the project initiated the provision of mineral blocks to farmers at no cost for a 2-month period. One block weighed approximately 2 kg and blocks were provided at a rate of one block per five goats. The cost of mineral blocks to farmers was subsidised by 50%. In Year 3 (2022), the project embarked on a collaborative effort to improve goat housing with farmers (Fig. 3). Metal roofing material was supplied to households constructing new wooden houses with elevated and slatted flooring. Additionally, in October 2022, concentrate feed was provided to households, initially to acclimate goats, followed by a 3-month trial. Finally, in November 2022, the project facilitated cross-visits between villages to enhance farmer-to-farmer learning.

Statistical analyses

Data were exported from CommCare® to Microsoft Excel. Data cleaning included stacking the surveys from different time points and performing spot checks to ensure correctness, recoding response variables to more succinct categories, and excluding variables from analysis if more than 15% of responses were missing. Data from the two surveys were maintained as separate spreadsheets. Within these datasets, a mix of continuous, binary, ordinal, and categorical variables were encountered. Summary statistics were calculated for each variable on the basis of proportions, means, and standard deviations. Proportions were based on the number of individual participants who answered specific questions, and not the overall number of respondents. In 2020, the BMS had 70 respondents, in 2021 it had 66, and in 2023 it had 52. In 2020, the MHS had 353 monthly survey records, in 2021 it had 324, and in 2022 it had 191 (over only 2 months at the beginning of 2022). Twelve binary variables recorded whether kidding had occurred ('1' for yes and '0' for no) per calendar month in the BMS, and 12 binary variables recorded when feed shortages occurred in the same format. These two sets of 12 variables were summarised into one first principal component each, derived from principal-component analysis. To assess differences among years, various statistical tests were conducted, including Fisher's exact test for categorical outcome variables, univariable logistic generalised linear mixed models (GLMMs) for binary outcome variables, univariable Poisson GLMMs for count outcome variables, and univariable linear mixed models for continuous outcome variables. All analyses incorporated district, village, and household as random effects, with village nested within district and household within village. Year was included as the fixed effect. All statistical computations were performed using R statistical software (RStudio Team 2023; version 2023.6.1.524).

Fig. 3. Goat housing design supported by the project in Savannakhet, Laos, 2022.

Results

Findings from benchmarking surveys (BMS)

Goat management practice changes

Farmers altered their goat husbandry practices and management significantly (all $P < 0.001$) from year to year

(Table 1). The linear trends were the growing number of farmers providing mineral blocks over time, which coincided with a reduction in the provision of salt *ad libitum*, a reduction in goats needing to be treated with drugs, and an increase in free-grazing of goats (without cut-and-carry) over time. The number of farmers who had a dedicated forage plot (i.e. growing forages) increased by 14% after the first year and then reached a plateau. Forage plot size was not collected in 2020 and was collected in irreconcilable units in 2023. In 2021, the mean forage plot size of households growing forages was 90 m^2 (s.d. = 140 m^2). Almost all farmers locked goats in secure housing at night-time and almost no

Table 1. Goat management practices conducted on smallholder goat farms in the past 12 months in Savannakhet, Lao PDR, as determined by three annualised benchmarking surveys.

Variable	2020		2021		2023		*P*-value
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	
Husbandry practices							
Lock up goats in secure house every night	68	68 (100.0)	61	52 (85.2)	52	49 (94.2)	<0.001[A]
Provide housing above the ground on a slatted floor	70	43 (61.4)	61	13 (21.3)	52	4 (7.7)	<0.001[A]
Provide salt *ad libitum*	70	47 (67.1)	61	23 (37.7)	52	14 (26.9)	<0.001[A]
Provide mineral block or mix	70	10 (14.3)	61	48 (78.7)	52	30 (57.7)	<0.001[A]
Have a dedicated forage plot to produce fodder	70	4 (5.7)	61	12 (19.7)	52	9 (17.3)	0.001[A]
Provide clean water in the goat house	70	47 (67.1)	61	21 (34.4)	52	20 (38.5)	<0.001[A]
Keep does behind when they are due to kid, so that they kid in or near the goat house	70	45 (64.3)	61	38 (62.3)	52	14 (26.9)	<0.001[A]
Keep kids behind in goat house after kidding	70	47 (67.1)	61	47 (77.0)	52	10 (19.2)	<0.001[A]
Treat sick goats with drugs	70	43 (61.4)	61	35 (57.4)	52	17 (32.7)	0.002[A]
Provide concentrate feed	70	10 (14.3)	61	0	52	10 (19.2)	<0.001[A]
Provide special feed to prepare goats for market	70	1 (1.4)	61	0	52	1 (1.9)	[E]
Vaccinate goats against disease	70	1 (1.4)	61	0	52	2 (3.8)	[E]
Free-grazing only (no cut-and-carry)	68	44 (63.8)	62	53 (85.5)	52	47 (90.4)	<0.001[A]
Response when goats have disease	69		62		52		
Farmer treats		58 (84.1)		25 (40.3)		15 (28.9)	<0.001[B]
External source treats (projects, village veterinary workers)		11 (15.9)		37 (59.7)		37 (71.2)	
Source of goat information	70		64		52		
Within village (friends, family, etc.)		59 (84.3)		1 (1.6)		6 (11.5)	<0.001[B]
Outside village (government, NGOs, media, traders, etc.)		11 (15.7)		63 (98.4)		46 (88.5)	
	N	***μ* ± s.d.**	***N***	***μ* ± s.d.**	***N***	***μ* ± s.d.**	
Other management practices							
Hours goats graze in wet season	70	6.0 ± 1.9	66	5.5 ± 1.7	52	5.5 ± 1.7	0.161[C]
Hours goats graze in dry season	70	7.8 ± 1.6	66	7.3 ± 1.9	52	7.3 ± 2.1	0.115[C]
Hours manage goats per day in wet season	70	3.6 ± 2.4	64	2.8 ± 1.6	52	3.5 ± 1.8	0.035[C]
Hours manage goats per day in dry season	70	3.9 ± 3.2	64	3.5 ± 2.5	52	4.2 ± 2.4	0.117[C]
Total hectares of land owned/used by farm	70	3.6 ± 3.5	66	4.2 ± 3.6	52	4.2 ± 4.0	0.232[C]
Age sell goats (months)	70	7.3 ± 3.0	63	7.4 ± 3.3	49	8.7 ± 3.4	0.040[C]
Number of weeks kids kept in goat house after kidding	47	1.7 ± 1.2	48	1.7 ± 2.1	13	2.1 ± 2.4	0.814[C]
Number of breeding does purchased annually	70	1.3 ± 5.5	61	0.1 ± 0.6	39	0.2 ± 0.6	<0.001[D]
Number of breeding bucks purchased annually	70	0.1 ± 0.5	61	0.0 ± 0.1	38	0.0 ± 0.2	[E]

N, total number of responses; *n*, number of households conducting the practice; *μ*, mean; s.d., standard deviation.
[A]Univariable logistic generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.
[B]Fisher's exact test for independence.
[C]Univariable linear mixed model with district, village and household coded as a random effect and year as the only fixed effect.
[D]Univariable poisson generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.
[E]*P*-value was not assessed because >95% of responses were the same.

farmers prepared goats for market with special feeding regimens, or vaccinated goats. No farmers castrated goats because traders prefer uncastrated goats for the Vietnam meat market.

Goats free-grazed for 5.5–6 h per day in the wet season. The daily duration of free-grazing was ~2 h longer in the dry season than in the wet season, owing to farmers needing to supervise goats in the wet season to keep them away from rice crops and aiming to minimise the associated time commitment, as well as dry-season feed scarcity requiring longer foraging times. The increased grazing duration in the dry season than in the wet season did not change over time ($P > 0.05$). Farmers spent an additional ~40 min managing goats per day in the dry season compared with the wet season. The reliance on free-grazing was necessary, with few farmers growing forages (6–17%) and farmers owning small plots of land (3.6–4.2 ha). Goats were predominantly grazed on communal land (77.0% in 2020, 69.4% in 2021 and 78.8% in 2023), as well as on land owned by the farmer themselves (52.7% in 2020, 30.6% in 2021 and 21.2% in 2023) and on land owned by relatives (17.6% in 2020, 0% in 2021 and 2023). Only one farmer grazed their goats on rented land.

Reproductive management was minimal, with almost no farmer purchasing breeding does or bucks. The average of 1.3 does purchased in 2020 appears to be an anomaly evidenced by a high standard deviation of ±5.5 (Table 1). The proportion of farmers that ensured that does gave birth in or near the goat house to facilitate colostrum provision decreased linearly over time and was only 26.9% in 2023, being a 35.4% reduction from the year before. On average, farmers kept does in or near the goat house at kidding for only ~2 weeks. Other trends were that the age in which farmers sold goats increased by 1.4 months over time ($P < 0.05$), and that farmers increasingly relied on project personnel for information on goat raising and to respond to goat illness ($P < 0.001$).

An anomalous finding was that the proportion of households providing housing above the ground on slatted flooring decreased significantly between 2020 and 2023 ($P < 0.001$). Goat housing is a permanent structure that generally does not revert to a more rudimentary structure over time. An increase in this proportion was expected over time because of the construction of improved housing on several farms as a result of project intervention.

Farm enterprises

Almost all farmers consistently grew rice (92.3–94.2%; $P = 0.581$), which confirms the dominance of rice-based systems in Laos (Table 2). Smaller and fluctuating proportions of farmers grew vegetables, corn, fruit and other crops (2.0–65.2%; all $P < 0.05$). The numbers of livestock species also significantly (all $P < 0.05$) varied year to year, with a consistent upward trend observed only in goat numbers, which increased by three head from 2020 to 2023. Over half of the farmers earnt non-farm income and this proportion remained steady ($P = 0.243$).

Table 2. Farm enterprises conducted on smallholder goat farms in the past 12 months in Savannakhet, Lao PDR, as determined by three annualised benchmarking surveys.

Enterprise	2020		2021		2023		*P*-value
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	
Number of farmers							
Rice	70	66 (94.3)	66	62 (93.9)	52	48 (92.3)	0.581[A]
Corn	70	11 (15.7)	66	4 (6.1)	52	1 (2.0)	0.014[A]
Vegetables	70	40 (57.1)	64	8 (12.5)	52	14 (26.9)	<0.001[A]
Fruit	70	23 (32.9)	66	5 (7.6)	52	7 (13.5)	<0.001[A]
Other crops	70	20 (28.6)	66	43 (65.2)	52	27 (51.9)	<0.001[A]
Number of farms with non-farm income	61	33 (54.1)	66	44 (66.7)	52	33 (63.5)	0.243[A]
	N	*μ* ± s.d.	*N*	*μ* ± s.d.	*N*	*μ* ± s.d.	
Number of stock owned							
Goats	70	9.0 ± 5.9	66	10.2 ± 7.5	52	12.0 ± 8.9	<0.001[B]
Pigs	70	0.9 ± 3.3	66	2.5 ± 8.3	52	1.1 ± 4.4	<0.001[B]
Cattle	70	6.5 ± 8.2	66	4.7 ± 5.4	52	4.8 ± 7.5	<0.001[B]
Buffalo	70	1.5 ± 2.4	66	1.1 ± 2.0	52	0.6 ± 1.9	<0.001[B]
Chicken	70	18.3 ± 15.7	66	19.6 ± 22.1	52	8.1 ± 8.2	<0.001[B]
Ducks	70	6.9 ± 9.9	66	7.2 ± 11.4	52	3.4 ± 5.0	<0.001[B]

N, total number of responses; *n*, number of households conducting activity; *μ*, mean; s.d., standard deviation.
[A]Univariable logistic generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.
[B]Univariable poisson generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.

Constraints

Farmers were asked whether they had experienced certain constraints on their farm in the past 12 months (Table 3). Farms constrained by orf virus in their goats, 'other' disease

Table 3. Constraints faced by farmers on smallholder goat farms in the past 12 months in Savannakhet, Lao PDR, as determined by three annualised benchmarking surveys.

Constraint	2020		2021		2023		*P*-value[A]
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	
Orf	70	52 (74.3)	61	20 (32.8)	40	8 (20.0)	<0.001
Diarrhoea	70	27 (38.6)	61	18 (29.5)	40	12 (30.0)	0.478
Other disease	70	25 (35.7)	61	14 (23.0)	40	4 (10.0)	0.007
Feed shortage	70	14 (20.0)	61	4 (6.6)	40	0	<0.001
Goats damage crops	70	4 (5.7)	61	2 (3.3)	40	6 (15.0)	0.067
Goats going missing	70	2 (2.9)	61	10 (16.4)	40	11 (27.5)	<0.001
Dog attack	70	4 (5.7)	62	9 (14.5)	40	8 (20.0)	0.059

N, total number of responses; *n*, number of households reporting the constraint.
[A]Univariable logistic generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.

and feed shortages significantly decreased over time ($P < 0.05$). Other diseases consisted of eye and respiratory infections, internal and external parasites and leg injuries and weakness. Diarrhoea was a constraint on about a third of farms and this remained steady over time ($P = 0.478$). Farms constrained by goats damaging crops and dog attacks trended upward, but the trend was not significant ($P > 0.05$). The proportion of holdings that were constrained by goats going missing significantly ($P < 0.001$) increased over time (Table 3).

Kidding times and feed shortages

The first principal components for months of kidding and feed shortages did not significantly ($P = 0.722$ and 0.742 respectively) differ among years, indicating that the patterns of kidding and feed shortages remained similar among years. This is reflected in Fig. 4 where the proportions do not change markedly among years and kidding occurs year-round. Peaks in kidding occurred in November–February (early dry season) and May–June (onset of wet season). Dips occurred from March to April (late dry season) and from July to August (mid-wed season). Feed shortages peaked between March and May (end of dry season) and August–October (end of wet season) and were low at other times. Of note, farmers reporting feed shortages did not always consider these as major constraints (Table 3).

Socioeconomics

Total annual household income (Lao Kip) and farm income (Lao Kip) significantly increased ($P < 0.05$) over time (Table 4), which was probably partially related to inflation, which occurred simultaneously. In contrast, total annual goat income (Lao Kip) remained constant, potentially related to farmers retaining goats for longer, evidenced by both sale age and herd size increasing over time (Table 4). Goat income represented approximately 11.7–20.3% of the total household income. The amount of family labour working on and off the farm remained consistent over the years ($P > 0.05$), with approximately three family members working on the farm and one or two working off farm.

Impacts of COVID-19

The second BMS was conducted in 2021 after a period of COVID-19 restrictions. To understand the impacts of these restrictions, households were asked how goat sale price and the quantity of goat traders had changed as a result of the COVID-19 pandemic. Of 64 households, 31 reported that goat sale price remained the same (48.4%), 22 reported that goat sale price decreased by 10–30% (34.4%), five reported that goat sale price increased by 10–30% (7.8%), four reported that goat sale price increased by >30% (6.3%), and two reported that goat sale price decreased by >30% (3.1%). Of 62 households, 34 reported that the quantity of traders decreased by 10–30% (54.8%), 23 reported that the quantity of traders had remained the same (37.1%), three reported that the quantity of traders decreased by >30% (4.8%) and two reported that the quantity of traders increased by 10–30% (3.2%).

Findings from monthly household survey (MHS)

The MHS recorded the proportion of holdings conducting practices in the past month, averaged by year. Hence, the MHS gives an indication of how consistently practices where implemented during the year, unlike the BMS, which

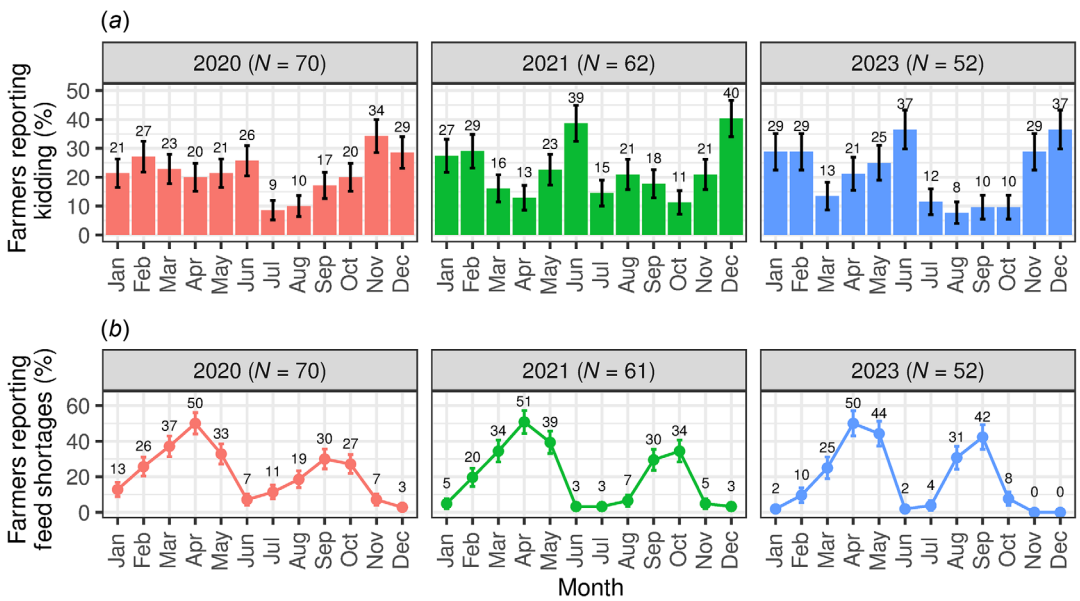

Fig. 4. Proportion of farmers reporting the months when (*a*) kidding and (*b*) goat feed shortages occurred in the past 12 months in Savannakhet, Lao PDR. *N*, total number of responses.

Table 4. Socioeconomics on smallholder goat farms in the past 12 months in Savannakhet, Lao PDR, as determined by three annualised benchmarking surveys.

Productivity variable	2020		2021		2023		*P*-value
	N	$\mu \pm$ s.d.	*N*	$\mu \pm$ s.d.	*N*	$\mu \pm$ s.d.	
Annual household income in Million Lao Kip (USD)[A]	61	13.8 ± 12.1 (1568 ± 1375)	66	21.0 ± 18.8 (2069 ± 1852)	52	23.0 ± 12.7 (1195 ± 660)	0.005[B]
Annual farm income in Million Lao Kip (USD)[A]	61	7.1 ± 5.9 (807 ± 670)	66	12.3 ± 14.8 (1212 ± 1458)	52	14.8 ± 13.0 (769 ± 675)	0.004[B]
Annual goat income in Million Lao Kip (USD)[A]	62	2.8 ± 4.1 (318 ± 466)	66	2.6 ± 4.8 (256 ± 473)	52	2.7 ± 4.9 (140 ± 255)	0.982[B]
No. of household members that work on farm	70	3.0 ± 1.6	66	3.3 ± 1.7	52	2.8 ± 1.3	0.340[C]
No. of household members that work off farm	70	1.4 ± 1.8	65	1.8 ± 1.6	52	1.9 ± 1.3	0.069[C]

N, total number of responses; μ, mean; s.d., standard deviation.
[A]Lao Kip converted to US$ on the basis of 1 US$ = 8800 Lao Kip (2020), 1 US$ = 10,150 Lao Kip (2021), 1 US$ = 19,250 Lao Kip (2023).
[B]Linear mixed model with district, village and household coded as a random effects and year as the only fixed effect. *P*-value refers to income in Lao kip, not US$.
[C]Poisson generalised linear mixed model with district, village and household coded as random effects and year as the only fixed effect.

indicates only whether the practice was implemented at all in the past 12 months. The MHS shows that providing mineral block or mix was consistently practiced throughout the year, whereas all other practices occurred sporadically (Table 5). This is indicated by half (47.8%) and three quarters (73.3%) of holdings providing a mineral block or mix each month in 2021 and 2022 respectively ($P < 0.001$), compared with less than a quarter of holdings conducting any other practice each month (Table 5). An exception was the practice of keeping kids behind in the goat house after kidding, which was practiced by over half (55.0%) of the farmers in 2022, a significant increase from 2021 (11.7%).

In disagreement with the BMS, the MHS found less variability in changes to the proportions of holdings conducting practices from year to year. The proportion of farms that provided salt *ad libitum,* had a dedicated forage plot, provided clean water in the goat house, and that treated sick goats with drugs in the past month did not significantly ($P > 0.05$) change between 2021 and 2022 (Table 5). Of households with forage plots, the overall average plot size was 90 m^2 (s.d. = 120 m^2), which was comparable to data from the BMS. Of note, questions on husbandry practices were added only to the MHS only in 2021 because of an error, so data were not available in 2020. In agreement with the BMS, no farmers

Table 5. Goat husbandry practices on smallholder goat farms in the past month in Savannakhet, Lao PDR, as determined by a monthly household survey.

Variable	2020		2021		2022		*P*-value
	N	*n* (%)	*N*	*n* (%)	*N*	*n* (%)	
Husbandry practices							
Provide salt *ad libitum*	0	–	324	23 (7.1)	191	5 (2.6)	0.423[A]
Provide a mineral block or mix	0	–	324	155 (47.8)	191	140 (73.3)	<0.001[A]
Have a dedicated forage plot to produce fodder	0	–	324	28 (8.6)	191	18 (9.4)	0.090[A]
Provide clean water in the goat house	0	–	324	14 (4.3)	191	6 (3.1)	[C]
Keep kids behind in goat house after kidding	0	–	324	38 (11.7)	191	105 (55.0)	<0.001[A]
Treat sick goats with drugs	0	–	324	80 (24.7)	191	22 (11.5)	0.621[A]
Provide concentrate feed	0	–	324	0	191	8 (4.2)	[C]
Provide special feed to prepare goats for market	0	–	324	0	191	14 (7.3)	[C]
Vaccinate goats against disease	0	–	324	0	191	0	[C]
Other							
Disease present in herd	353	177 (50.1)	324	128 (39.5)	191	63 (33.0)	<0.001[A]
	N	$\mu \pm$ s.d.	*N*	$\mu \pm$ s.d.	*N*	$\mu \pm$ s.d.	
Number of goats in the herd	353	10.6 ± 6.3	324	12.9 ± 7.1	191	13.6 ± 7.5	<0.001[B]

N, total number of responses; *n*, number of households with variable; μ, mean; s.d., standard deviation.
[A]Binomial generalised linear mixed model, with month, district, village and household coded as random effects and year as the only fixed effect.
[B]Poisson generalised linear mixed model, with month, district, village and household coded as random effects and year as the only fixed effect.
[C]*P*-value was not assessed because >95% of responses were the same.

vaccinated goats against disease and the number of goats in the herd significantly ($P < 0.001$) increased over time by three head. In agreement with disease constraints decreasing over time in the BMS (Table 3), the proportions of herds reporting disease presence in the past month significantly ($P < 0.001$) decreased over time, from about half of herds to a third of herds. An additional finding was that when farmers sold goats, over half of the goats sold were <12-month-old males. Farmers kept most female goats for breeding.

Discussion

Smallholder goat management practices in Laos are consistent with those of smallholder systems in other countries that are characterised by small herds, uncontrolled breeding, mixed livestock and cropping enterprises, and very limited commercial nutritional or veterinary inputs (Kumar *et al.* 2016; Monau *et al.* 2017; Ouchene-Khelifi *et al.* 2021). The two surveys conducted provided some evidence that the development approach that comprised regular visits, a mix of formal and informal training, subsidised or incentivised provision of agricultural inputs and a focus on forage growing, veterinary treatments, mineral blocks, improved goat housing, and supplementary concentrate feeding, achieved some improved practices.

The most consistent practice across the annual and monthly survey was the significant increase in mineral block use over time. Also, on the basis of trends, the two surveys mirrored the increase in farmers growing forages over time, the decrease in sick goats being treated with drugs, and the increase in farmers providing concentrate feed. However, the exact years and sizes of proportions did not align across surveys. Regardless, these four practices directly reflected the interventions promoted by the project, except for goat housing, which lacked corresponding survey questions in the MHS and resulted in erroneous data in the BMS. These trends and the approximate consistencies among surveys indicate that the intervention program did achieve some beneficial practice change. However, the study design did not enable formal evaluations of the effect of the interventions because there was not a control group, and the study did not assess ongoing practice changes post-project. The inability to include husbandry questions in the first year of the MHS detracted from the ability to assess trends across both surveys.

Nevertheless, the data suggested that mineral blocks and perhaps other nutrient blocks have potential for high rates of adoption. The acceptability of block technology for cattle and buffalo has been reported previously in Laos (Windsor *et al.* 2019; Olmo *et al.* 2020; Windsor *et al.* 2021) and is attributed to its ease of use, low risk, low labour and land inputs, utility in encouraging animals to return to housing, and inexpensiveness. A qualitative study conducted within the same study population also reported the tendency for interventions with low labour, land and capital investment to be more readily implemented by farmers (Liehr *et al.* 2024*b*). Also, a study from India on urea–molasses mineral blocks confirmed high adoption (35%) in association with development extension programs (Nimbalkar *et al.* 2020). This shows that development extension programs can effectively enhance the adoption of block technology. However, the mineral blocks sourced by the LS/2017/034 project were rudimentary, containing only sodium, magnesium, potassium, calcium, sulfur, phosphorus, zinc, copper, cobalt, selenium, iodine, iron and manganese. Whereas the project did not collect data on block consumption rate, holdings generally purchased one to five blocks every second month at the subsidised cost of 10,000 Lao kip/block. Also, the project did not investigate mineral deficiencies beforehand. Further research is recommended to assess nutrient blocks containing non-protein nitrogen (urea) and molasses as the latter is widely available in Laos. Urea–molasses blocks are not widely available, so mineral blocks may be necessary starting points. The presence of two large sugarcane factories in Savannakhet province and the recent opening of a mineral block factory in northern Laos may improve availability. Future projects should also investigate mineral deficiencies in goats because mineral supplementation works best when used to address deficiencies. The strategy of providing a 2-month trial period followed by 50% subsidisation of mineral block costs is recommended, noting that uptake of fully priced blocks was not tested. This strategy was effective in both testing and verifying farmer willingness to pay.

The BMS and MHS corroborated that reporting of herd-level disease significantly decreased over time (Table 3). The confidence in this trend is strengthened by the decrease in goats being treated with drugs over time in both the BMS and MHS. Although this was an expected outcome resulting from the monthly veterinary visits, this intervention is unsustainable after project conclusion, owing to the cost of routine veterinary visit being prohibitive to most farmers and veterinarians being scarce throughout rural Laos. The continuation of veterinary care is recommended in a scaled-down version driven by village veterinary workers (VVWs) operating microbusinesses as described by Health Poverty Action (2017). VVWs are locally based individuals who provide para-veterinarian services in Laos. Their focus on local and inexpensive treatments to address the key goat disease syndromes is recommended. In Laos, these are orf-like lip and facial lesions, diarrhoea, and eye infections (Windsor *et al.* 2017; Phengvilaysouk *et al.* 2022). On the basis of field observations and veterinary diagnostics, VVWs should treat orf with emollients such as glycerine, to soften scab material combined with iodine-based antiseptics to limit secondary bacterial infection (Roberson *et al.* 2012). Vaccination to control orf is unlikely to be practical, given the sporadic occurrence of the disease and apparent development of persistent immunity in adult goats (Jayasekara PP, unpubl.

data). To overcome eye infections, broad-spectrum antibacterial eye drops applied to affected animals on arrival at their housing in the evening and prior to release in the morning is recommended (Jayasekara *et al.* 2024). Diarrhoea was not reduced in this study, which is an ongoing challenge in developed countries (Anzuino *et al.* 2019). The cost–benefit to farmers of paying VVWs for veterinary treatments remains unknown (Mondry *et al.* 2005) and should be investigated if VVWs are to have a sustainable role in driving improved animal disease outcomes in Laos.

The inconsistent keeping of does and kids in the goat house after kidding provides an opportunity for further research as reproduction rate underpins profitability (Inchaisri *et al.* 2010). Controlled breeding is unlikely to be suitable in the short to medium term, owing to lacking infrastructure to segregate goats by sex and superstitions against castration (Matsumoto *et al.* 2017). However, boosting neonatal management is recommended to increase kid survival as an entry point. Confining prenatal does to enable assistance with difficult births and ensuring that colostrum feeding occurs within 2 h of birth is recommended. Confining neonatal kids to enable them to be protected from the elements and conserve energy and to allow dams to free-range more widely is recommended. This is based on the prior experience of the authors with tropical meat goats in Fiji and the association of these practices with improved kid survival, growth rate and reduced diarrhoea prevalence reported in dairy operations (Dwyer *et al.* 2016; Bélanger-Naud *et al.* 2021; Zamuner *et al.* 2023). There is a lack of published research on the impact of these practices on kid survival in smallholder meat goat production. Another question for further research is whether does should be confined alongside their kids. Kid and doe confinement may increase horizontal transmission of respiratory pathogens (Bélanger-Naud *et al.* 2021) and reduce lactation if the supplementary feed is inferior to what is gained from free-grazing.

Enhanced nutrition during April and May (late dry season), when high rates of kidding and feed shortages occur (Fig. 2), is another potential simple option to improve productivity. An obvious entry point is to increase grazing duration. Even though dry-season grazing was 2 h longer than the wet-season grazing, it was only 8 h per day (Table 1). Lengthening grazing can be achieved by releasing goats at sunrise instead of 9–10 am, which was common. The LS/2017/034 project discussed increasing this duration with farmers. Their feedback was that releasing goats at sunrise increased exposure to parasites. Silva *et al.* (2008) confirmed that there is no effect of time of day on the vertical migration of *Haemonchus contortus* third-stage larvae (L3) on pasture. The practice of anhydrobiosis observed for the L3 of key small ruminant nematode parasites under dry conditions (Lettini and Sukhdeo 2006) mitigates against extensive migration of infective larvae, which cannot feed and have limited energy stores. Therefore, earlier release of goats warrants further investigation as well as education of farmers on the parasite life cycle.

Forage growing is another option to increase April–May nutrition. However, the moderately low forage adoption rates (Table 1) forebode challenges in achieving widespread adoption. Even on adopting farms, forage did not persist into the dry season. The reason for its recession is probably the direct grazing of forage plots instead of harvesting, and a lack of irrigation. The fundamental barrier against forage growing is the ready availability of communal grasslands, which satisfies subsistence, as inferred by Stur *et al.* (2002). Farmer complacency with subsistent levels of production will require knowledge and awareness building to overcome. Another barrier is the lack of availability of vegetative material or seeds to re-establish forage crops each year. Perennial species should be investigated to overcome this supply challenge. Other options to improve dry-season nutrition include the provision of non-protein nitrogen supplementation (urea), molasses, crop residues such as casava leaves, and concentrate feeding. Further research is needed to expand the use of crop by-products and tree fodder because controlled trials support their benefits on liveweight in goats in Laos (Phengvichith and Ledin 2007; Kongmanila 2012).

With the benefit of hindsight, it is strongly recommended to not alter longitudinal survey questions after survey commencement. Although this is obvious and was intended to improve the questions and shorten the survey, it led to key survey questions not being comparable across years. For this reason, several useful core questions were inadvertently removed. Also, incorrect survey question interpretation cannot be ruled out from subjective surveys. It is suspected this occurred for the question on whether farmers provided housing above the ground on a slatted floor. This should have increased over time, rather than decreasing significantly. Incorporating objective assessments into farmer surveys is a strategy to verify survey responses; however, it increases cost. The criteria used to select villages and households also limits the applicability of the findings to households and villages in central Laos with a greater emphasis on goats, and adequate land to grow forages. Further, the small sample size of the study, calculated using a higher precision level of 10%, means that all proportions presented should be interpreted with a ±10% margin of error.

Finally, as herd size increased between 2020 and 2023, farmers did not sell proportionately more goats. Instead, they opted to increase herd size. It is likely that herd size significantly increased over the course of the project because this was reflected in both surveys. The average herd size grew by about three goats, representing a 20–30% increase. The increase in herd size was unlikely to be a result of smaller, non-viable goat farms dropping out of the surveys/project over time because the households that that did not participate in the 2021 survey had a higher average goat herd size than was the overall average in 2020. The households that that did not participate in the 2023 survey had a lower average goat herd size than was the overall average in 2020, but only by

about one goat. The overall increase in goat herd size over time was probably aided by reduced disease afforded by enhanced nutrition and disease management. The evidence that farmers stockpiled their goats is that goat income in Lao Kip remained constant across years (Table 4). Also, the average age that farmers reported selling goats increased by ~2 months (Table 1). This trend supports the notion that farmers continued selling goats on a needs basis (Liehr *et al*. 2024*a*). COVID-19 was potentially another influencing factor, with half of farmers reporting fluctuations in goat sale price and the quantity of goat traders due to COVID-19. These changes may have affected farmer willingness to sell goats during the pandemic. However, as goat demand recovered immediately following COVID-19 restrictions being rescinded in Vietnam (Nguyễn *et al*. 2022), it is unlikely that the pandemic was the sole driver of changes to goat sales in Laos.

Conclusions

Smallholder goat management in Laos follows the characteristics of low-input management employed in many developing countries. Hence, low cost and simple interventions are likely to appeal to most farmers. These may include providing multi-nutrient blocks to goats, particularly in the late dry season (April–May), increasing daily grazing duration from the current 6–8 h to as much as possible, and confining prenatal does and kids to ensure colostrum provision to kids, frequent monitoring, and pen cleaning. Providing partial incentives can help promote practice change such as subsidising the cost of mineral blocks during a trial period and providing metal roofing to farmers who constructed improved goat housing. The development of village veterinary worker or animal health service microbusinesses is recommended to sustain the delivery of basic veterinary treatments post-project. It is recommended that these microbusinesses focus on locally available and inexpensive treatments for orf, eye infection, and diarrhoea.

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Data availability. The data that support this study are available on request.

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Author affiliations

[A]School of Environmental and Rural Science, The University of New England, Armidale, NSW 2351, Australia.

[B]National Agriculture and Forestry Research Institute, Vientiane, Lao PDR.

[C]Gulbali Institute, Charles Sturt University, Albury, NSW 2640, Australia.

[D]Present address: Elizabeth Macarthur Agricultural Institute, NSW Department of Primary Industries and Regional Development, Woodbridge Road, Menangle, NSW 2568, Australia.